1
00:00:05,510 --> 00:00:03,990
nasa's jet propulsion laboratory

2
00:00:08,310 --> 00:00:05,520
presents

3
00:00:10,310 --> 00:00:08,320
the von carmen lecture a series of talks

4
00:00:13,669 --> 00:00:10,320
by scientists and engineers who are

5
00:00:27,990 --> 00:00:13,679
exploring our planet our solar system

6
00:00:31,509 --> 00:00:29,750
good evening ladies and gentlemen how's

7
00:00:33,030 --> 00:00:31,519
everyone tonight

8
00:00:34,549 --> 00:00:33,040
good well thanks again for coming out to

9
00:00:36,630 --> 00:00:34,559
join us this evening

10
00:00:38,869 --> 00:00:36,640
where is the best place to find living

11
00:00:41,110 --> 00:00:38,879
life beyond earth it may be that the

12
00:00:43,270 --> 00:00:41,120
small ice covered moons of jupiter and

13
00:00:45,430 --> 00:00:43,280

saturn harbor some of the most habitable

14
00:00:47,430 --> 00:00:45,440
real estate in our solar system

15
00:00:48,950 --> 00:00:47,440
life loves liquid water and these moons

16
00:00:50,229 --> 00:00:48,960
have lots of it

17
00:00:52,069 --> 00:00:50,239
tonight's lecture will explain the

18
00:00:53,990 --> 00:00:52,079
science behind why we think we know

19
00:00:55,830 --> 00:00:54,000
these oceans exist and what we know

20
00:00:57,990 --> 00:00:55,840
about the conditions on these worlds

21
00:01:00,150 --> 00:00:58,000
while focusing on jupiter's moon europa

22
00:01:01,189 --> 00:01:00,160
which is a top priority for future nasa

23
00:01:02,869 --> 00:01:01,199
missions

24
00:01:04,469 --> 00:01:02,879
and we'll also show how the exploration

25
00:01:07,270 --> 00:01:04,479
of earth's ocean is helping to inform

26
00:01:09,030 --> 00:01:07,280
our understanding of worlds like europa

27
00:01:11,109 --> 00:01:09,040
born and raised in manchester vermont

28
00:01:13,030 --> 00:01:11,119
tonight's guest earned two bachelor's

29
00:01:14,950 --> 00:01:13,040
degrees from dartmouth college and his

30
00:01:16,070 --> 00:01:14,960
master's and phd from stanford

31
00:01:17,910 --> 00:01:16,080
university

32
00:01:19,670 --> 00:01:17,920
he is now the deputy chief scientist for

33
00:01:21,830 --> 00:01:19,680
solar system exploration right here at

34
00:01:23,910 --> 00:01:21,840
nasa's jet propulsion laboratory

35
00:01:25,990 --> 00:01:23,920
his research his research focuses on the

36
00:01:28,070 --> 00:01:26,000
origin evolution and distribution of

37
00:01:30,230 --> 00:01:28,080
life in the solar system with an

38
00:01:31,910 --> 00:01:30,240

emphasis on moons of the outer solar

39
00:01:33,030 --> 00:01:31,920
system that likely have liquid water

40
00:01:35,109 --> 00:01:33,040
oceans

41
00:01:36,789 --> 00:01:35,119
his work involves numerical modeling

42
00:01:38,710 --> 00:01:36,799
laboratory experiments and field

43
00:01:40,469 --> 00:01:38,720
campaigns exploring some of earth's most

44
00:01:41,830 --> 00:01:40,479
extreme environments

45
00:01:44,069 --> 00:01:41,840
his field work has brought him to the

46
00:01:46,550 --> 00:01:44,079
dry valleys of antarctica the depths of

47
00:01:48,149 --> 00:01:46,560
the earth's oceans the icy permafrost of

48
00:01:51,350 --> 00:01:48,159
alaska and to the glaciers of

49
00:01:53,749 --> 00:01:51,360
kilimanjaro in 2011 he was selected as a

50
00:01:55,109 --> 00:01:53,759
national geographic emerging explorer

51
00:01:56,630 --> 00:01:55,119
and has been featured in several

52
00:01:59,670 --> 00:01:56,640
television documentaries for national

53
00:02:02,069 --> 00:01:59,680
geographic discovery and pbs and was

54
00:02:04,389 --> 00:02:02,079
featured in the imax film aliens of the

55
00:02:06,230 --> 00:02:04,399
deep he has made nine dives to the

56
00:02:08,710 --> 00:02:06,240
bottom of the ocean and was also a

57
00:02:11,430 --> 00:02:08,720
scientist on board james cameron's 2012

58
00:02:12,790 --> 00:02:11,440
dive to the bottom of the mariana trench

59
00:02:19,510 --> 00:02:12,800
ladies and gentlemen please help me

60
00:02:25,750 --> 00:02:22,790
thank you mark

61
00:02:32,309 --> 00:02:28,390
thank you very much

62
00:02:33,670 --> 00:02:32,319
the the question of whether or not life

63
00:02:36,550 --> 00:02:33,680

exists

64
00:02:40,070 --> 00:02:36,560
beyond earth is one of the oldest

65
00:02:42,949 --> 00:02:40,080
most primordial unanswered questions

66
00:02:45,670 --> 00:02:42,959
that humanity still has and that's

67
00:02:47,430 --> 00:02:45,680
much of what motivates my interest in

68
00:02:49,110 --> 00:02:47,440
these ocean worlds of the outer solar

69
00:02:52,309 --> 00:02:49,120
system

70
00:02:54,790 --> 00:02:52,319
but uh just to be clear tonight i will

71
00:02:56,309 --> 00:02:54,800
not be covering

72
00:02:58,149 --> 00:02:56,319
ufos

73
00:02:59,670 --> 00:02:58,159
alien abductions

74
00:03:02,630 --> 00:02:59,680
furry little creatures from other

75
00:03:04,790 --> 00:03:02,640
planets with three eyes

76
00:03:06,390 --> 00:03:04,800
when i talk about the search for life

77
00:03:09,430 --> 00:03:06,400
elsewhere

78
00:03:11,270 --> 00:03:09,440
i'm focused on even the tiniest of

79
00:03:14,229 --> 00:03:11,280
little microbes

80
00:03:17,030 --> 00:03:14,239
uh even that discovery

81
00:03:19,030 --> 00:03:17,040
uh the tiniest speck on some distant

82
00:03:21,350 --> 00:03:19,040
world would revolutionize our

83
00:03:24,470 --> 00:03:21,360
understanding of the science of biology

84
00:03:26,710 --> 00:03:24,480
and how our universe works

85
00:03:29,110 --> 00:03:26,720
now this is a question that has

86
00:03:30,710 --> 00:03:29,120
fascinated me since i was a young boy

87
00:03:32,789 --> 00:03:30,720
as mark mentioned

88
00:03:34,949 --> 00:03:32,799

i grew up in a small town in vermont and

89
00:03:36,869 --> 00:03:34,959
and looking at this picture

90
00:03:41,270 --> 00:03:36,879
i guess it's it's no surprise that i

91
00:03:45,910 --> 00:03:43,190
and i attribute i attribute my

92
00:03:48,229 --> 00:03:45,920
fascination with the stars largely to

93
00:03:49,350 --> 00:03:48,239
the clear night skies that vermont

94
00:03:51,509 --> 00:03:49,360
provided

95
00:03:54,149 --> 00:03:51,519
but books like this

96
00:03:55,830 --> 00:03:54,159
also helped to captivate

97
00:03:59,030 --> 00:03:55,840
my imagination

98
00:04:00,630 --> 00:03:59,040
showing a rather optimistic

99
00:04:03,910 --> 00:04:00,640
vision for

100
00:04:05,990 --> 00:04:03,920
aliens in jupiter's atmosphere

101
00:04:07,750 --> 00:04:06,000
some sort of martian creature with

102
00:04:10,630 --> 00:04:07,760
massive ears

103
00:04:12,550 --> 00:04:10,640
and even some sort of dinosaur surviving

104
00:04:14,949 --> 00:04:12,560
somehow on the surface of a world like

105
00:04:17,349 --> 00:04:14,959
europa

106
00:04:19,349 --> 00:04:17,359
but i'd like to show this image for

107
00:04:21,749 --> 00:04:19,359
another reason and that is that

108
00:04:24,230 --> 00:04:21,759
in that background you can see that

109
00:04:26,469 --> 00:04:24,240
these mountains of vermont

110
00:04:28,950 --> 00:04:26,479
our entire planet

111
00:04:31,110 --> 00:04:28,960
is covered with life

112
00:04:32,310 --> 00:04:31,120
and one one of the the beautiful

113
00:04:34,150 --> 00:04:32,320

challenges

114
00:04:35,270 --> 00:04:34,160
that we face in our search for life

115
00:04:38,230 --> 00:04:35,280
elsewhere

116
00:04:41,830 --> 00:04:38,240
is that our home planet

117
00:04:42,950 --> 00:04:41,840
from north south east west high low hot

118
00:04:46,629 --> 00:04:42,960
cold

119
00:04:49,590 --> 00:04:46,639
our planet is teeming with life

120
00:04:52,230 --> 00:04:49,600
and in fact it's hard to find

121
00:04:54,830 --> 00:04:52,240
a spot on our home planet

122
00:04:58,070 --> 00:04:54,840
that does not harbor

123
00:04:59,990 --> 00:04:58,080
life and the story of our search for

124
00:05:02,469 --> 00:05:00,000
life elsewhere

125
00:05:03,670 --> 00:05:02,479
is in part the story

126
00:05:06,390 --> 00:05:03,680
of

127
00:05:07,990 --> 00:05:06,400
this beautiful little planet

128
00:05:09,749 --> 00:05:08,000
reaching out

129
00:05:12,870 --> 00:05:09,759
into the solar system

130
00:05:15,590 --> 00:05:12,880
through our robotic spacecraft each of

131
00:05:17,670 --> 00:05:15,600
these lines here denotes a mission that

132
00:05:20,150 --> 00:05:17,680
has gone out to one of the

133
00:05:24,950 --> 00:05:20,160
worlds in our solar system

134
00:05:26,790 --> 00:05:24,960
as we know here we're just over 50 years

135
00:05:29,590 --> 00:05:26,800
into this endeavor of

136
00:05:31,029 --> 00:05:29,600
searching uh for life beyond

137
00:05:33,189 --> 00:05:31,039
beyond earth

138
00:05:35,270 --> 00:05:33,199

searching for understanding the origins

139
00:05:40,790 --> 00:05:35,280
of our solar system and someday

140
00:05:47,590 --> 00:05:44,870
but our effort to find life elsewhere

141
00:05:48,469 --> 00:05:47,600
begins with understanding life on earth

142
00:05:50,150 --> 00:05:48,479
which

143
00:05:51,590 --> 00:05:50,160
brings us back to this tiny little

144
00:05:53,670 --> 00:05:51,600
valley nestled in the green mountains of

145
00:05:56,710 --> 00:05:53,680
vermont

146
00:05:59,110 --> 00:05:56,720
finding signs of life on a distant world

147
00:06:01,749 --> 00:05:59,120
is complicated by the fact that life

148
00:06:04,230 --> 00:06:01,759
and biological processes have played

149
00:06:05,110 --> 00:06:04,240
such varied and significant roles on

150
00:06:08,950 --> 00:06:05,120
earth

151
00:06:11,510 --> 00:06:08,960
both in the past and in the present

152
00:06:13,029 --> 00:06:11,520
how will we know if we found life on a

153
00:06:15,990 --> 00:06:13,039
distant world

154
00:06:19,110 --> 00:06:16,000
what guidance can life on earth provide

155
00:06:21,990 --> 00:06:19,120
for us in this search

156
00:06:23,670 --> 00:06:22,000
well it would be easy enough if we if we

157
00:06:26,870 --> 00:06:23,680
landed on a planet

158
00:06:28,150 --> 00:06:26,880
and saw trees and

159
00:06:31,270 --> 00:06:28,160
grass

160
00:06:33,510 --> 00:06:31,280
and a tennis court

161
00:06:35,189 --> 00:06:33,520
but so far that hasn't happened and the

162
00:06:37,670 --> 00:06:35,199
situation quickly gets a lot more

163
00:06:40,550 --> 00:06:37,680

complicated when you consider

164
00:06:42,950 --> 00:06:40,560
simple forms and the signs that they

165
00:06:44,309 --> 00:06:42,960
leave on a planet

166
00:06:46,469 --> 00:06:44,319
these mountains serve as a useful

167
00:06:48,710 --> 00:06:46,479
example if you peel away

168
00:06:50,550 --> 00:06:48,720
all these trees and the grass and even

169
00:06:52,469 --> 00:06:50,560
the tennis court you find

170
00:06:55,990 --> 00:06:52,479
these rocks

171
00:06:57,270 --> 00:06:56,000
these are blocks of marble

172
00:06:59,990 --> 00:06:57,280
mined

173
00:07:01,749 --> 00:07:00,000
from this old marble quarry

174
00:07:03,189 --> 00:07:01,759
some of this marble went on to be used

175
00:07:05,749 --> 00:07:03,199
in various monuments and buildings

176
00:07:06,870 --> 00:07:05,759
around the country and around the globe

177
00:07:08,950 --> 00:07:06,880
and

178
00:07:12,070 --> 00:07:08,960
it has its

179
00:07:15,270 --> 00:07:12,080
roots in a story that began

180
00:07:18,230 --> 00:07:15,280
some 350 million years ago

181
00:07:22,550 --> 00:07:18,240
if you rewind the clock of time

182
00:07:26,309 --> 00:07:22,560
in this old mountain we've got layers

183
00:07:28,870 --> 00:07:26,319
layers that represent an ancient seabed

184
00:07:30,390 --> 00:07:28,880
layers in an ancient ocean that existed

185
00:07:34,230 --> 00:07:30,400
in the appalachian region

186
00:07:35,510 --> 00:07:34,240
some 350 million years ago

187
00:07:37,350 --> 00:07:35,520
gradually

188
00:07:39,589 --> 00:07:37,360

sand and sediments

189
00:07:41,510 --> 00:07:39,599
fell out of that ocean and formed the

190
00:07:43,670 --> 00:07:41,520
seabed

191
00:07:44,390 --> 00:07:43,680
some of the sediments

192
00:07:45,830 --> 00:07:44,400
were

193
00:07:52,550 --> 00:07:45,840
the

194
00:07:54,950 --> 00:07:52,560
creatures called foraminifera

195
00:07:57,990 --> 00:07:54,960
the the tests of foraminifera are

196
00:07:59,350 --> 00:07:58,000
calcite calcium carbonate and in this

197
00:08:01,589 --> 00:07:59,360
ancient ocean

198
00:08:03,589 --> 00:08:01,599
these organisms lived and died and their

199
00:08:05,510 --> 00:08:03,599
their tests gradually sedimented onto

200
00:08:07,589 --> 00:08:05,520
the seafloor

201
00:08:10,390 --> 00:08:07,599
and with time

202
00:08:13,350 --> 00:08:10,400
that sea floor underwent changes in

203
00:08:16,150 --> 00:08:13,360
temperature and pressure gradually

204
00:08:19,670 --> 00:08:16,160
transforming that

205
00:08:22,869 --> 00:08:19,680
that evidence of life in the past

206
00:08:24,869 --> 00:08:22,879
into limestone and eventually into this

207
00:08:26,469 --> 00:08:24,879
rock that we know and love and call

208
00:08:30,390 --> 00:08:26,479
marble

209
00:08:32,389 --> 00:08:30,400
that just looking at it

210
00:08:34,550 --> 00:08:32,399
you don't see any

211
00:08:36,630 --> 00:08:34,560
any sign of

212
00:08:39,269 --> 00:08:36,640
those complex organisms the complex

213
00:08:41,990 --> 00:08:39,279

tests of the four amino

214
00:08:44,470 --> 00:08:42,000
you have no direct evidence

215
00:08:47,430 --> 00:08:44,480
just by examining it that that this

216
00:08:49,350 --> 00:08:47,440
tells a story of life in an ancient

217
00:08:51,670 --> 00:08:49,360
ocean

218
00:08:53,910 --> 00:08:51,680
and yet to the trained eye

219
00:08:56,310 --> 00:08:53,920
through our study of life on earth

220
00:08:58,630 --> 00:08:56,320
through our understanding of

221
00:09:00,790 --> 00:08:58,640
biology and biological processes on our

222
00:09:01,590 --> 00:09:00,800
home planet we've come to appreciate

223
00:09:03,110 --> 00:09:01,600
that

224
00:09:05,910 --> 00:09:03,120
for the most part

225
00:09:07,670 --> 00:09:05,920
when we find this stone called marble on

226
00:09:10,550 --> 00:09:07,680
earth

227
00:09:13,350 --> 00:09:10,560
it tells a story of past life on our

228
00:09:16,550 --> 00:09:15,190
so what if we were to go to a planet

229
00:09:21,030 --> 00:09:16,560
like this

230
00:09:22,870 --> 00:09:21,040
and examine rocks

231
00:09:24,630 --> 00:09:22,880
like these

232
00:09:25,910 --> 00:09:24,640
a landscape

233
00:09:28,949 --> 00:09:25,920
showing

234
00:09:31,509 --> 00:09:28,959
dotted with ancient stream beds

235
00:09:34,949 --> 00:09:31,519
what if our curiosity rover

236
00:09:37,670 --> 00:09:34,959
were to rove up and nestle up against

237
00:09:39,670 --> 00:09:37,680
a nice big block of marble

238
00:09:42,949 --> 00:09:39,680

what would we conclude

239
00:09:44,470 --> 00:09:42,959
about that as a sign of past life on

240
00:09:46,630 --> 00:09:44,480
mars

241
00:09:48,389 --> 00:09:46,640
the answer is frankly we don't know

242
00:09:49,910 --> 00:09:48,399
that's part of the challenge

243
00:09:52,310 --> 00:09:49,920
trying to figure out both the the

244
00:09:53,509 --> 00:09:52,320
context and the formation and the

245
00:09:56,070 --> 00:09:53,519
history

246
00:09:58,310 --> 00:09:56,080
of a geological region on a world like

247
00:10:01,990 --> 00:09:58,320
mars and the adventure is just beginning

248
00:10:04,870 --> 00:10:02,000
who knows we may someday find

249
00:10:09,030 --> 00:10:04,880
rocks like marble or perhaps even more

250
00:10:12,949 --> 00:10:10,949
but as much as i love the planet mars

251
00:10:15,590 --> 00:10:12,959
and our search for life on mars for the

252
00:10:17,350 --> 00:10:15,600
most part we are looking for

253
00:10:19,990 --> 00:10:17,360
life in the past we are looking for

254
00:10:22,069 --> 00:10:20,000
evidence of life in the rock record on

255
00:10:24,230 --> 00:10:22,079
mars

256
00:10:26,949 --> 00:10:24,240
i want to find living life life that is

257
00:10:30,310 --> 00:10:26,959
alive today life that is living in an

258
00:10:32,710 --> 00:10:30,320
environment that is habitable today

259
00:10:35,269 --> 00:10:32,720
coupled with that

260
00:10:36,790 --> 00:10:35,279
i want to explore worlds

261
00:10:38,470 --> 00:10:36,800
where we think

262
00:10:42,550 --> 00:10:38,480
life may have gone

263
00:10:45,030 --> 00:10:42,560

undergone a second independent origin

264
00:10:47,509 --> 00:10:45,040
from life on earth

265
00:10:50,550 --> 00:10:47,519
probing this question of is the origin

266
00:10:52,550 --> 00:10:50,560
of life easy or is it hard

267
00:10:54,470 --> 00:10:52,560
and on mars there are some confusing

268
00:10:55,829 --> 00:10:54,480
components there you see

269
00:10:58,230 --> 00:10:55,839
early on in the history of the solar

270
00:11:00,630 --> 00:10:58,240
system mars and the earth traded

271
00:11:02,870 --> 00:11:00,640
material back and forth and in fact it's

272
00:11:05,670 --> 00:11:02,880
it continues into the modern day

273
00:11:07,430 --> 00:11:05,680
and so if we were to go to mars

274
00:11:09,430 --> 00:11:07,440
and find

275
00:11:12,069 --> 00:11:09,440
a fossil well first of all we would have

276
00:11:15,269 --> 00:11:12,079
a a hard time

277
00:11:17,030 --> 00:11:15,279
discerning the biochemistry of a fossil

278
00:11:19,670 --> 00:11:17,040
but even if we were to go to mars and

279
00:11:22,790 --> 00:11:19,680
find living life and discover that it

280
00:11:25,110 --> 00:11:22,800
was based on dna and rna and proteins

281
00:11:26,790 --> 00:11:25,120
we would then have a challenge of

282
00:11:29,430 --> 00:11:26,800
figuring out whether or not

283
00:11:30,949 --> 00:11:29,440
that life was related to the tree of

284
00:11:32,710 --> 00:11:30,959
life here on earth

285
00:11:34,310 --> 00:11:32,720
or whether or not it represented a

286
00:11:36,389 --> 00:11:34,320
second origin

287
00:11:39,030 --> 00:11:36,399
because of this this transfer of

288
00:11:40,790 --> 00:11:39,040

material back and forth

289
00:11:42,949 --> 00:11:40,800
this comes to that issue of

290
00:11:44,550 --> 00:11:42,959
of the tree of life here on earth

291
00:11:46,790 --> 00:11:44,560
our tree of life has changed

292
00:11:48,310 --> 00:11:46,800
dramatically over the time period in

293
00:11:49,190 --> 00:11:48,320
which we've been exploring the solar

294
00:11:51,030 --> 00:11:49,200
system

295
00:11:53,269 --> 00:11:51,040
just some 50 to 60 years ago if you

296
00:11:55,750 --> 00:11:53,279
mentioned the tree of life this is the

297
00:11:56,790 --> 00:11:55,760
image that would come to mind an image

298
00:12:00,470 --> 00:11:56,800
of

299
00:12:03,430 --> 00:12:00,480
neanderthals not too far away

300
00:12:05,350 --> 00:12:03,440
in evolutionary timeline from dinosaurs

301
00:12:08,310 --> 00:12:05,360
and other large creatures

302
00:12:10,790 --> 00:12:08,320
but we now know that the tree of life

303
00:12:13,590 --> 00:12:10,800
that we once conceived of is just

304
00:12:16,949 --> 00:12:13,600
the tiniest of branches

305
00:12:19,590 --> 00:12:16,959
on a tree of life that is dominated

306
00:12:22,790 --> 00:12:19,600
by microbial life forms

307
00:12:25,750 --> 00:12:22,800
we are just that tiniest little twig

308
00:12:29,509 --> 00:12:25,760
in this beautiful tree of life with

309
00:12:31,670 --> 00:12:29,519
archaea bacteria and eukaryotes most of

310
00:12:34,550 --> 00:12:31,680
which are single-celled

311
00:12:37,110 --> 00:12:34,560
microbial organisms

312
00:12:38,870 --> 00:12:37,120
so might there be a second tree of life

313
00:12:42,150 --> 00:12:38,880

out there in our solar system

314
00:12:44,470 --> 00:12:42,160
could there be a forest of trees of life

315
00:12:46,949 --> 00:12:44,480
in our solar system and beyond

316
00:12:49,430 --> 00:12:46,959
to probe that question

317
00:12:51,590 --> 00:12:49,440
i think we need to explore these ocean

318
00:12:53,030 --> 00:12:51,600
worlds of the outer solar system

319
00:12:54,550 --> 00:12:53,040
shown here

320
00:12:56,470 --> 00:12:54,560
is a portrait

321
00:12:59,110 --> 00:12:56,480
of the ocean worlds of our solar system

322
00:13:01,110 --> 00:12:59,120
at the center of course is the earth

323
00:13:02,470 --> 00:13:01,120
and around the earth i've placed europa

324
00:13:05,269 --> 00:13:02,480
ganymede

325
00:13:08,069 --> 00:13:05,279
and callisto three moons of jupiter

326
00:13:11,670 --> 00:13:08,079
enceladus and and titan two moons of

327
00:13:12,710 --> 00:13:11,680
saturn and even neptune's curious moon

328
00:13:13,910 --> 00:13:12,720
triton

329
00:13:16,389 --> 00:13:13,920
we think

330
00:13:17,910 --> 00:13:16,399
could possibly harbor

331
00:13:19,430 --> 00:13:17,920
an ocean

332
00:13:20,790 --> 00:13:19,440
in that case it would be liquid water

333
00:13:21,910 --> 00:13:20,800
mixed with ammonia and a few other

334
00:13:23,670 --> 00:13:21,920
things

335
00:13:26,069 --> 00:13:23,680
but these moons of the outer solar

336
00:13:28,470 --> 00:13:26,079
system are covered in ice and beneath

337
00:13:31,350 --> 00:13:28,480
their icy shells we have good reason to

338
00:13:34,629 --> 00:13:31,360

believe that vast quantities of liquid

339
00:13:36,629 --> 00:13:34,639
water are there today and may have

340
00:13:39,350 --> 00:13:36,639
persisted for much of the history of the

341
00:13:43,030 --> 00:13:41,110
this information this knowledge is

342
00:13:44,470 --> 00:13:43,040
really transforming our understanding of

343
00:13:46,550 --> 00:13:44,480
what it takes for a world to be

344
00:13:49,189 --> 00:13:46,560
habitable in the early days of planetary

345
00:13:52,870 --> 00:13:49,199
science and astronomy

346
00:13:55,910 --> 00:13:52,880
the idea of a habitable zone was defined

347
00:13:58,470 --> 00:13:55,920
largely by the need to be at just

348
00:14:00,069 --> 00:13:58,480
the right distance from your parent star

349
00:14:01,110 --> 00:14:00,079
such that you had enough energy to

350
00:14:03,750 --> 00:14:01,120
maintain

351
00:14:06,230 --> 00:14:03,760
a liquid water ocean on the surface in

352
00:14:09,030 --> 00:14:06,240
contact with an atmosphere

353
00:14:11,189 --> 00:14:09,040
and and that ocean could cycle with a

354
00:14:12,790 --> 00:14:11,199
sea floor and and the atmosphere and so

355
00:14:14,629 --> 00:14:12,800
we had this sort of goldilocks scenario

356
00:14:16,949 --> 00:14:14,639
where if you're at the earth sun

357
00:14:18,870 --> 00:14:16,959
distance you could maintain a liquid

358
00:14:21,430 --> 00:14:18,880
water ocean on the surface

359
00:14:23,829 --> 00:14:21,440
if you got too close you got too hot

360
00:14:25,829 --> 00:14:23,839
like venus and you could not sustain an

361
00:14:28,470 --> 00:14:25,839
ocean if you got too far away you got

362
00:14:30,310 --> 00:14:28,480
too cold and you could not sustain an

363
00:14:33,509 --> 00:14:30,320

ocean

364
00:14:36,470 --> 00:14:33,519
solar system are telling us is that this

365
00:14:38,629 --> 00:14:36,480
is kind of an old goldilocks

366
00:14:40,949 --> 00:14:38,639
there's a new goldilocks in town and

367
00:14:41,910 --> 00:14:40,959
it's a goldilocks that is

368
00:14:43,829 --> 00:14:41,920
not

369
00:14:46,069 --> 00:14:43,839
mediated by distance from your parent

370
00:14:48,389 --> 00:14:46,079
star and the energy that you get from

371
00:14:51,670 --> 00:14:48,399
your parent star instead it's a

372
00:14:55,350 --> 00:14:51,680
goldilocks zone for habitability that is

373
00:14:57,670 --> 00:14:55,360
mediated by tidal energy dissipation

374
00:15:00,069 --> 00:14:57,680
and there's no better example for this

375
00:15:02,230 --> 00:15:00,079
kind of energy dynamic than jupiter's

376
00:15:04,870 --> 00:15:02,240
moon io shown here

377
00:15:06,310 --> 00:15:04,880
and what you're seeing on io in that

378
00:15:09,430 --> 00:15:06,320
northern region

379
00:15:12,870 --> 00:15:09,440
is a volcanic eruption

380
00:15:15,590 --> 00:15:12,880
io is the most volcanically active body

381
00:15:17,990 --> 00:15:15,600
in our solar system more volcanically

382
00:15:20,790 --> 00:15:18,000
active than the earth

383
00:15:23,350 --> 00:15:20,800
and it is so volcanically active

384
00:15:24,629 --> 00:15:23,360
because of the tidal tug and pole that

385
00:15:27,269 --> 00:15:24,639
it experiences

386
00:15:29,990 --> 00:15:27,279
as it orbits jupiter in its slightly

387
00:15:32,470 --> 00:15:30,000
elliptical orbit

388
00:15:33,749 --> 00:15:32,480

so the jovian system the large moons of

389
00:15:35,430 --> 00:15:33,759
jupiter

390
00:15:37,910 --> 00:15:35,440
provide us with this sort of new

391
00:15:40,230 --> 00:15:37,920
goldilocks for habitability

392
00:15:43,269 --> 00:15:40,240
where io is kind of like venus io has

393
00:15:45,749 --> 00:15:43,279
too much energy just being dissipated io

394
00:15:48,629 --> 00:15:45,759
lost any water that it once had the

395
00:15:51,430 --> 00:15:48,639
yellows the reds the whites that you see

396
00:15:54,550 --> 00:15:51,440
those are all various forms of sulfur

397
00:15:56,389 --> 00:15:54,560
from the volcanic eruptions

398
00:15:57,590 --> 00:15:56,399
at the farther reaches you've got

399
00:16:01,670 --> 00:15:57,600
callisto

400
00:16:03,749 --> 00:16:01,680
though we think it has an ocean

401
00:16:06,230 --> 00:16:03,759
callisto's ocean is trapped beneath a

402
00:16:08,310 --> 00:16:06,240
very thick layer of ice and that layer

403
00:16:10,629 --> 00:16:08,320
of ice is quite old as evidenced by all

404
00:16:13,269 --> 00:16:10,639
the the pock marks on the surface ice of

405
00:16:15,749 --> 00:16:13,279
callisto all of those little pock marks

406
00:16:18,069 --> 00:16:15,759
are craters

407
00:16:20,550 --> 00:16:18,079
but in the middle

408
00:16:22,870 --> 00:16:20,560
in this sort of new goldilocks zone for

409
00:16:25,189 --> 00:16:22,880
habitability we've got europa and

410
00:16:26,069 --> 00:16:25,199
ganymede and europa in particular we

411
00:16:28,710 --> 00:16:26,079
think

412
00:16:30,629 --> 00:16:28,720
might satisfy the conditions for

413
00:16:32,389 --> 00:16:30,639

habitability as we've come to know and

414
00:16:34,710 --> 00:16:32,399
love it for for life on earth and that

415
00:16:37,749 --> 00:16:34,720
is needing liquid water

416
00:16:39,749 --> 00:16:37,759
access to the building blocks of life

417
00:16:43,430 --> 00:16:39,759
and some energy some chemical

418
00:16:45,749 --> 00:16:43,440
disequilibrium that life can harness

419
00:16:47,269 --> 00:16:45,759
and again part of why these worlds are

420
00:16:49,189 --> 00:16:47,279
so compelling in our search for life

421
00:16:51,829 --> 00:16:49,199
elsewhere is that if we've learned

422
00:16:53,509 --> 00:16:51,839
anything from life on earth it's that

423
00:16:55,269 --> 00:16:53,519
where you find liquid water you

424
00:16:57,590 --> 00:16:55,279
generally find life

425
00:16:59,910 --> 00:16:57,600
from life in these extreme environments

426
00:17:01,509 --> 00:16:59,920
from hydrothermal vents hot springs in

427
00:17:04,549 --> 00:17:01,519
the rift valley

428
00:17:06,470 --> 00:17:04,559
the coldest regions of antarctica

429
00:17:09,189 --> 00:17:06,480
where there's liquid water even if it's

430
00:17:09,990 --> 00:17:09,199
transient life somehow somehow finds a

431
00:17:12,230 --> 00:17:10,000
way

432
00:17:12,949 --> 00:17:12,240
from life in extreme environments

433
00:17:16,069 --> 00:17:12,959
to

434
00:17:18,470 --> 00:17:16,079
life of extreme lifestyles

435
00:17:21,189 --> 00:17:18,480
life on earth all depends on liquid

436
00:17:24,549 --> 00:17:21,199
water and and this also helps to

437
00:17:26,549 --> 00:17:24,559
underscore this issue of

438
00:17:28,549 --> 00:17:26,559

searching for a different biochemistry a

439
00:17:29,750 --> 00:17:28,559
different tree of life

440
00:17:31,270 --> 00:17:29,760
um

441
00:17:33,510 --> 00:17:31,280
for all of the

442
00:17:35,669 --> 00:17:33,520
the the crazy life forms from the

443
00:17:36,870 --> 00:17:35,679
tiniest microbe to the craziest rock

444
00:17:39,669 --> 00:17:36,880
star

445
00:17:41,270 --> 00:17:39,679
we are all not only connected by the dna

446
00:17:43,590 --> 00:17:41,280
tree of life

447
00:17:45,909 --> 00:17:43,600
but we're also connected by the same

448
00:17:49,029 --> 00:17:45,919
fundamental biochemistry of dna rna

449
00:17:50,789 --> 00:17:49,039
proteins and even atp

450
00:17:52,390 --> 00:17:50,799
is there a different way of getting the

451
00:17:53,750 --> 00:17:52,400
business of life done is there a

452
00:17:54,710 --> 00:17:53,760
different way

453
00:18:00,150 --> 00:17:54,720
to

454
00:18:02,390 --> 00:18:00,160
don't know

455
00:18:04,310 --> 00:18:02,400
but when it comes to these oceans how do

456
00:18:05,830 --> 00:18:04,320
we think we know they exist well it all

457
00:18:07,990 --> 00:18:05,840
begins of course

458
00:18:09,909 --> 00:18:08,000
with our exploration

459
00:18:11,190 --> 00:18:09,919
and here at jpl

460
00:18:13,110 --> 00:18:11,200
uh

461
00:18:15,750 --> 00:18:13,120
we've been at the forefront of exploring

462
00:18:17,270 --> 00:18:15,760
these worlds for europa and enceladus

463
00:18:19,990 --> 00:18:17,280

the champions of that exploration are

464
00:18:21,830 --> 00:18:20,000
the cassini spacecraft shown at left and

465
00:18:22,630 --> 00:18:21,840
the galileo spacecraft shown at upper

466
00:18:25,110 --> 00:18:22,640
right

467
00:18:26,549 --> 00:18:25,120
and of course these these spacecraft

468
00:18:28,549 --> 00:18:26,559
would be useless if we couldn't actually

469
00:18:30,470 --> 00:18:28,559
get the signal back and the deep space

470
00:18:33,190 --> 00:18:30,480
network shown at the bottom right is

471
00:18:35,590 --> 00:18:33,200
essential in getting that signal back

472
00:18:38,710 --> 00:18:35,600
and it's through these spacecraft

473
00:18:41,669 --> 00:18:38,720
that we've managed to reveal the beauty

474
00:18:43,510 --> 00:18:41,679
of worlds like saturn and i'll begin

475
00:18:46,470 --> 00:18:43,520
with a little bit of a description of

476
00:18:47,669 --> 00:18:46,480
why we think we know an ocean

477
00:18:52,390 --> 00:18:47,679
exists

478
00:18:57,190 --> 00:18:54,549
here is enceladus

479
00:18:58,710 --> 00:18:57,200
with saturn and saturn's rings

480
00:19:00,310 --> 00:18:58,720
in the background

481
00:19:02,950 --> 00:19:00,320
enceladus is a curious moon it's only

482
00:19:05,990 --> 00:19:02,960
about 500 kilometers in diameter

483
00:19:07,350 --> 00:19:06,000
uh not too much bigger uh in span than

484
00:19:09,190 --> 00:19:07,360
than sort of the uh

485
00:19:10,630 --> 00:19:09,200
the great lakes region

486
00:19:12,950 --> 00:19:10,640
but you notice something immediately

487
00:19:15,029 --> 00:19:12,960
when you take a closer look at enceladus

488
00:19:17,029 --> 00:19:15,039

the northern hemisphere is dotted with

489
00:19:19,110 --> 00:19:17,039
all these craters whereas the southern

490
00:19:20,950 --> 00:19:19,120
hemisphere

491
00:19:24,470 --> 00:19:20,960
they're essentially no craters but you

492
00:19:27,110 --> 00:19:24,480
have these tiger stripe fractures

493
00:19:28,470 --> 00:19:27,120
the surface is telling us the story

494
00:19:30,150 --> 00:19:28,480
in the north

495
00:19:32,390 --> 00:19:30,160
those craters have been around for a

496
00:19:34,070 --> 00:19:32,400
long time in the south the absence of

497
00:19:37,190 --> 00:19:34,080
craters tells us that this is a fresh

498
00:19:42,070 --> 00:19:39,590
and these fractures which we've now come

499
00:19:43,830 --> 00:19:42,080
to call the tiger stripes if we take a

500
00:19:46,390 --> 00:19:43,840
closer look

501
00:19:49,510 --> 00:19:46,400
and get just the right angle as the

502
00:19:50,630 --> 00:19:49,520
cassini spacecraft has has managed to uh

503
00:19:52,070 --> 00:19:50,640
to enable

504
00:19:54,549 --> 00:19:52,080
we get what i would argue is one of the

505
00:19:56,150 --> 00:19:54,559
most beautiful images

506
00:20:00,870 --> 00:19:56,160
ever collected in our solar system

507
00:20:03,270 --> 00:20:00,880
exploration an image of plumes erupting

508
00:20:05,510 --> 00:20:03,280
out of fractures from the south polar

509
00:20:06,390 --> 00:20:05,520
terrain of enceladus

510
00:20:08,710 --> 00:20:06,400
um

511
00:20:11,350 --> 00:20:08,720
you know normally when i give this talk

512
00:20:14,070 --> 00:20:11,360
audiences ooh and ah at the fractures

513
00:20:16,950 --> 00:20:14,080

um clearly this is a a uh

514
00:20:19,830 --> 00:20:16,960
the the jpl audience has seen uh uh

515
00:20:21,430 --> 00:20:19,840
enceladus all over

516
00:20:23,029 --> 00:20:21,440
of course part of what's exciting is not

517
00:20:23,990 --> 00:20:23,039
only can you see the plumes but you can

518
00:20:27,190 --> 00:20:24,000
see

519
00:20:28,870 --> 00:20:27,200
fresh snow or fresh uh deposits along

520
00:20:30,390 --> 00:20:28,880
some of these fractures

521
00:20:32,830 --> 00:20:30,400
and zooming in

522
00:20:36,310 --> 00:20:32,840
one of the the highest

523
00:20:38,310 --> 00:20:36,320
resolution mosaics of enceladus

524
00:20:40,470 --> 00:20:38,320
shows these fractures up close where

525
00:20:43,029 --> 00:20:40,480
these boulders along some of the

526
00:20:44,630 --> 00:20:43,039
fractures are just a few meters in

527
00:20:45,909 --> 00:20:44,640
diameter

528
00:20:47,590 --> 00:20:45,919
and part of

529
00:20:49,750 --> 00:20:47,600
what of course we want to accomplish

530
00:20:52,070 --> 00:20:49,760
with our future of exploration

531
00:20:53,350 --> 00:20:52,080
is developing and designing the robotic

532
00:20:56,310 --> 00:20:53,360
spacecraft

533
00:20:58,230 --> 00:20:56,320
that will dive into these fractures

534
00:21:00,630 --> 00:20:58,240
down into these regions where we have

535
00:21:03,110 --> 00:21:00,640
good knowledge of plumes coming up

536
00:21:04,950 --> 00:21:03,120
connecting to an ocean

537
00:21:07,750 --> 00:21:04,960
below

538
00:21:09,750 --> 00:21:07,760

the sunlight here gives you some

539
00:21:12,310 --> 00:21:09,760
view into the deepest regions of some of

540
00:21:15,110 --> 00:21:12,320
these cracks and in a few of these

541
00:21:18,230 --> 00:21:15,120
pockets are where those fractures

542
00:21:20,070 --> 00:21:18,240
are where those plumes are coming out

543
00:21:22,149 --> 00:21:20,080
so on enceladus we've got this curious

544
00:21:23,510 --> 00:21:22,159
situation where the ocean is literally

545
00:21:26,070 --> 00:21:23,520
jumping out at us

546
00:21:28,710 --> 00:21:26,080
the the cassini spacecraft has flown to

547
00:21:32,950 --> 00:21:28,720
within 25 kilometers of enceladus

548
00:21:35,110 --> 00:21:32,960
surface it's sampled what we think is

549
00:21:37,190 --> 00:21:35,120
material derived from the ocean

550
00:21:39,590 --> 00:21:37,200
determined that there are salts in that

551
00:21:41,350 --> 00:21:39,600
water that there are organics in that

552
00:21:44,549 --> 00:21:41,360
water that there are compounds like

553
00:21:46,390 --> 00:21:44,559
carbon dioxide and methane in that water

554
00:21:50,070 --> 00:21:46,400
which could of course be quite useful

555
00:21:52,710 --> 00:21:50,080
from an astrobiological standpoint

556
00:21:56,390 --> 00:21:52,720
now at europa the situation is quite a

557
00:21:59,110 --> 00:21:57,669
enceladus

558
00:22:01,430 --> 00:21:59,120
we can see

559
00:22:03,750 --> 00:22:01,440
is active today

560
00:22:06,789 --> 00:22:03,760
europa the evidence for activity the

561
00:22:09,669 --> 00:22:06,799
evidence for plumes on europa is still

562
00:22:11,750 --> 00:22:09,679
under study and is a bit tenuous

563
00:22:14,789 --> 00:22:11,760

but europa is a much larger world it's

564
00:22:17,270 --> 00:22:14,799
about 3 000 kilometers in diameter and

565
00:22:20,470 --> 00:22:17,280
any plumes that we would expect to erupt

566
00:22:22,549 --> 00:22:20,480
on on europa would not go nearly as high

567
00:22:26,149 --> 00:22:22,559
as the plumes on on enceladus which

568
00:22:27,590 --> 00:22:26,159
extend outward for some 500 kilometers

569
00:22:29,029 --> 00:22:27,600
but nevertheless we think that the

570
00:22:30,470 --> 00:22:29,039
fracturing that we're seeing in this

571
00:22:33,510 --> 00:22:30,480
surface ice

572
00:22:36,149 --> 00:22:33,520
is in part caused by the tidal energy

573
00:22:38,950 --> 00:22:36,159
dissipation uh in the past perhaps in

574
00:22:41,909 --> 00:22:38,960
the present creating these these

575
00:22:44,310 --> 00:22:41,919
fractures and lineaments

576
00:22:46,310 --> 00:22:44,320
this ocean is of course maintained

577
00:22:47,990 --> 00:22:46,320
through this tidal inter energy

578
00:22:50,470 --> 00:22:48,000
interaction europa is about the size of

579
00:22:54,070 --> 00:22:50,480
our own moon but orbits jupiter which is

580
00:22:57,590 --> 00:22:54,080
some 318 times as massive as the earth

581
00:23:00,630 --> 00:22:57,600
and so the liquid water ocean on europa

582
00:23:01,669 --> 00:23:00,640
is about 100 kilometers deep by our best

583
00:23:03,590 --> 00:23:01,679
estimates

584
00:23:06,870 --> 00:23:03,600
and if you do the math it turns out that

585
00:23:08,390 --> 00:23:06,880
europa's ocean contains roughly two to

586
00:23:10,710 --> 00:23:08,400
three times the volume

587
00:23:14,070 --> 00:23:10,720
of all the liquid water in the oceans

588
00:23:15,909 --> 00:23:14,080

seas and lakes on earth

589
00:23:17,830 --> 00:23:15,919
showing that pictorially

590
00:23:19,350 --> 00:23:17,840
here's an image

591
00:23:20,310 --> 00:23:19,360
that some colleagues at woods hole put

592
00:23:22,950 --> 00:23:20,320
together

593
00:23:25,110 --> 00:23:22,960
showing all of the water on earth rolled

594
00:23:25,990 --> 00:23:25,120
up into a blue

595
00:23:30,230 --> 00:23:26,000
ball

596
00:23:31,350 --> 00:23:30,240
that blue marble is all of earth's water

597
00:23:32,870 --> 00:23:31,360
now the first thing that you should

598
00:23:34,390 --> 00:23:32,880
appreciate when you see this image is

599
00:23:37,350 --> 00:23:34,400
that of course we need to take care of

600
00:23:40,630 --> 00:23:37,360
our home planet and protect the uh the

601
00:23:42,870 --> 00:23:40,640
scarce water that we have here

602
00:23:44,470 --> 00:23:42,880
if you do the same calculation

603
00:23:46,710 --> 00:23:44,480
for europa

604
00:23:48,870 --> 00:23:46,720
you end up with a blue marble that

605
00:23:50,710 --> 00:23:48,880
contains about two to three times the

606
00:23:52,470 --> 00:23:50,720
volume of all the liquid water found

607
00:23:54,950 --> 00:23:52,480
here

608
00:23:58,149 --> 00:23:54,960
now as i mentioned on europa we don't

609
00:23:59,990 --> 00:23:58,159
have the smoking gun of plumes erupting

610
00:24:01,029 --> 00:24:00,000
we haven't seen any new fractures

611
00:24:03,590 --> 00:24:01,039
forming

612
00:24:05,990 --> 00:24:03,600
that i would argue is largely due to

613
00:24:07,830 --> 00:24:06,000

limitations in in our data limitations

614
00:24:11,510 --> 00:24:07,840
in and what's been returned by the

615
00:24:13,350 --> 00:24:11,520
voyager and galileo spacecraft

616
00:24:15,510 --> 00:24:13,360
but we have very good reason to believe

617
00:24:18,390 --> 00:24:15,520
that that ocean exists

618
00:24:22,070 --> 00:24:18,400
and the discovery of this ocean

619
00:24:23,510 --> 00:24:22,080
i like to break into three easy pieces

620
00:24:27,350 --> 00:24:23,520
the first piece

621
00:24:31,350 --> 00:24:29,590
much of what i do here at jpl is

622
00:24:35,990 --> 00:24:31,360
spectroscopy

623
00:24:37,909 --> 00:24:36,000
is basically a scientist fancy word for

624
00:24:39,909 --> 00:24:37,919
studying rainbows

625
00:24:41,669 --> 00:24:39,919
if you take a rainbow

626
00:24:43,669 --> 00:24:41,679
and turn it on its side

627
00:24:44,789 --> 00:24:43,679
and look at the intensity of the

628
00:24:47,110 --> 00:24:44,799
different colors the different

629
00:24:48,070 --> 00:24:47,120
wavelengths

630
00:24:49,830 --> 00:24:48,080
that

631
00:24:51,669 --> 00:24:49,840
is essentially a spectrum

632
00:24:54,149 --> 00:24:51,679
and by looking at the variations and

633
00:24:55,590 --> 00:24:54,159
intensity of the various colors

634
00:24:56,870 --> 00:24:55,600
you can reveal

635
00:24:58,390 --> 00:24:56,880
important information about the

636
00:25:00,149 --> 00:24:58,400
composition of

637
00:25:01,909 --> 00:25:00,159
the water and the atmosphere the other

638
00:25:04,230 --> 00:25:01,919

compounds in our atmosphere the

639
00:25:06,230 --> 00:25:04,240
composition of our sun

640
00:25:08,630 --> 00:25:06,240
and so spectroscopy is an incredibly

641
00:25:10,789 --> 00:25:08,640
useful tool for getting at surface and

642
00:25:12,470 --> 00:25:10,799
gaseous compositions and that's exactly

643
00:25:16,230 --> 00:25:12,480
what astronomers did back in the late

644
00:25:18,310 --> 00:25:16,240
1950s and 1960s they turned telescopes

645
00:25:19,990 --> 00:25:18,320
to the jovian system

646
00:25:21,510 --> 00:25:20,000
and measured

647
00:25:22,470 --> 00:25:21,520
the surface of europa and what they

648
00:25:23,510 --> 00:25:22,480
found

649
00:25:25,750 --> 00:25:23,520
is this

650
00:25:26,950 --> 00:25:25,760
an infrared spectrum an infrared rainbow

651
00:25:30,230 --> 00:25:26,960
turned on its side creating this

652
00:25:32,549 --> 00:25:30,240
spectrum with a highly diagnostic

653
00:25:34,710 --> 00:25:32,559
stepwise function of with absorptions at

654
00:25:38,470 --> 00:25:34,720
one and a half and two microns

655
00:25:40,310 --> 00:25:38,480
that is indicative of water ice

656
00:25:42,549 --> 00:25:40,320
and so by making that rainbow connection

657
00:25:45,029 --> 00:25:42,559
by doing the spectroscopy

658
00:25:47,990 --> 00:25:45,039
of europa scientists were able to first

659
00:25:50,149 --> 00:25:48,000
discover that europa's surface

660
00:25:52,390 --> 00:25:50,159
is at least covered with water in the

661
00:25:54,870 --> 00:25:52,400
solid phase

662
00:25:57,669 --> 00:25:54,880
the second piece of the puzzle

663
00:25:58,950 --> 00:25:57,679

is to babysit a spacecraft

664
00:26:01,430 --> 00:25:58,960
and

665
00:26:02,390 --> 00:26:01,440
the spacecraft being babysat

666
00:26:05,350 --> 00:26:02,400
was

667
00:26:07,830 --> 00:26:05,360
galileo and the babysitter

668
00:26:10,149 --> 00:26:07,840
is the deep space network

669
00:26:12,390 --> 00:26:10,159
by carefully monitoring the position of

670
00:26:13,830 --> 00:26:12,400
the galileo spacecraft as it flew by

671
00:26:15,110 --> 00:26:13,840
europa

672
00:26:17,190 --> 00:26:15,120
the deep space network and the

673
00:26:19,269 --> 00:26:17,200
scientists working on

674
00:26:20,230 --> 00:26:19,279
tracking the spacecraft were able to

675
00:26:22,390 --> 00:26:20,240
measure

676
00:26:25,750 --> 00:26:22,400
the slightest of deviations due to

677
00:26:27,990 --> 00:26:25,760
variations in europa's gravity

678
00:26:29,830 --> 00:26:28,000
and through that determination which

679
00:26:32,149 --> 00:26:29,840
involves a lot of math

680
00:26:33,590 --> 00:26:32,159
that i won't go into tonight

681
00:26:37,029 --> 00:26:33,600
though i imagine some members of this

682
00:26:39,430 --> 00:26:37,039
audience would love to dive into this

683
00:26:41,190 --> 00:26:39,440
through careful analysis of the gravity

684
00:26:42,950 --> 00:26:41,200
perturbations that were experienced by

685
00:26:43,990 --> 00:26:42,960
the galileo spacecraft as it flew by

686
00:26:46,390 --> 00:26:44,000
europa

687
00:26:48,630 --> 00:26:46,400
and doing the gravity inversion for the

688
00:26:50,870 --> 00:26:48,640

moment of inertia

689
00:26:53,110 --> 00:26:50,880
that leads to

690
00:26:54,070 --> 00:26:53,120
an internal mass distribution or

691
00:26:56,710 --> 00:26:54,080
internal

692
00:26:59,909 --> 00:26:56,720
density distribution for europa where

693
00:27:03,029 --> 00:26:59,919
we've got an iron or an iron sulfur core

694
00:27:05,510 --> 00:27:03,039
a silicate or rocky mantle

695
00:27:08,070 --> 00:27:05,520
and then an outer layer a layer of

696
00:27:11,029 --> 00:27:08,080
roughly 100 to 200 kilometers

697
00:27:12,950 --> 00:27:11,039
of unit density material

698
00:27:14,870 --> 00:27:12,960
and the simplest explanation for that

699
00:27:18,149 --> 00:27:14,880
unit density material

700
00:27:19,990 --> 00:27:18,159
is water in either liquid or solid phase

701
00:27:21,669 --> 00:27:20,000
now the the gravity information is

702
00:27:23,590 --> 00:27:21,679
insufficient to reveal the density

703
00:27:25,430 --> 00:27:23,600
difference between solid and liquid

704
00:27:27,830 --> 00:27:25,440
water and so

705
00:27:30,310 --> 00:27:27,840
the the second piece of the puzzle

706
00:27:32,310 --> 00:27:30,320
leaves us with this picture of europa

707
00:27:34,630 --> 00:27:32,320
where we've got a lot of water but we

708
00:27:36,230 --> 00:27:34,640
don't yet have an ocean

709
00:27:38,630 --> 00:27:36,240
to get to the ocean we need the final

710
00:27:40,149 --> 00:27:38,640
piece of the puzzle and that i like to

711
00:27:43,350 --> 00:27:40,159
make the analogy to

712
00:27:45,190 --> 00:27:43,360
adhering to airport security

713
00:27:47,269 --> 00:27:45,200

and uh

714
00:27:49,269 --> 00:27:47,279
my apologies for this fuzzy picture this

715
00:27:51,110 --> 00:27:49,279
is a picture that i took at at

716
00:27:53,430 --> 00:27:51,120
john f kennedy airport

717
00:27:55,990 --> 00:27:53,440
uh and i was trying not to get arrested

718
00:27:57,669 --> 00:27:56,000
so it's a it's a little bit blurry

719
00:27:59,350 --> 00:27:57,679
but so what happens when you walk

720
00:28:01,269 --> 00:27:59,360
through a metal detector at an airport

721
00:28:04,710 --> 00:28:01,279
what's happening is that you're walking

722
00:28:06,389 --> 00:28:04,720
through a time-varying magnetic field

723
00:28:08,950 --> 00:28:06,399
and if you've got a conductor in your

724
00:28:11,430 --> 00:28:08,960
pocket that time-varying magnetic field

725
00:28:13,590 --> 00:28:11,440
in that little doorway gives rise to

726
00:28:15,350 --> 00:28:13,600
induced electric currents

727
00:28:17,590 --> 00:28:15,360
in that conductor in your pocket and

728
00:28:19,990 --> 00:28:17,600
that those induced electric currents

729
00:28:21,669 --> 00:28:20,000
give rise to an induced magnetic field

730
00:28:22,789 --> 00:28:21,679
and within that little doorway are

731
00:28:25,269 --> 00:28:22,799
special

732
00:28:27,430 --> 00:28:25,279
detectors that are searching for

733
00:28:29,669 --> 00:28:27,440
that induced magnetic field and the

734
00:28:31,909 --> 00:28:29,679
alarm goes off

735
00:28:34,389 --> 00:28:31,919
well out at europa when the galileo

736
00:28:37,909 --> 00:28:34,399
spacecraft flew by europa

737
00:28:41,190 --> 00:28:37,919
the alarm essentially went off

738
00:28:43,430 --> 00:28:41,200

galileo had a fancy compass on board a

739
00:28:44,389 --> 00:28:43,440
magnetometer and that magnetometer was

740
00:28:45,510 --> 00:28:44,399
able to

741
00:28:48,230 --> 00:28:45,520
detect

742
00:28:50,950 --> 00:28:48,240
an induced magnetic field

743
00:28:52,149 --> 00:28:50,960
around europa a magnetic field that was

744
00:28:54,070 --> 00:28:52,159
not

745
00:28:57,350 --> 00:28:54,080
intrinsic to europa

746
00:29:00,070 --> 00:28:57,360
but which was being caused and mediated

747
00:29:01,350 --> 00:29:00,080
by jupiter's incredibly strong time

748
00:29:03,110 --> 00:29:01,360
varying field

749
00:29:05,190 --> 00:29:03,120
again a lot of math

750
00:29:07,669 --> 00:29:05,200
that i won't go into tonight but what

751
00:29:10,149 --> 00:29:07,679
this third piece of the puzzle leads to

752
00:29:11,669 --> 00:29:10,159
is that you need some near surface

753
00:29:13,190 --> 00:29:11,679
conducting layer

754
00:29:14,310 --> 00:29:13,200
analogous to the conductor in your

755
00:29:16,950 --> 00:29:14,320
pocket when you're walking through

756
00:29:19,110 --> 00:29:16,960
airport security you need some conductor

757
00:29:20,950 --> 00:29:19,120
in your pocket to create that induced

758
00:29:23,269 --> 00:29:20,960
magnetic field

759
00:29:25,190 --> 00:29:23,279
and the best explanation for that

760
00:29:28,710 --> 00:29:25,200
induced magnetic field

761
00:29:30,789 --> 00:29:28,720
is a salty liquid water layer near the

762
00:29:32,870 --> 00:29:30,799
surface of europa

763
00:29:35,110 --> 00:29:32,880

an iron core sure that's conductive but

764
00:29:36,710 --> 00:29:35,120
it's too far away from the spacecraft to

765
00:29:37,750 --> 00:29:36,720
explain the induced magnetic field

766
00:29:39,510 --> 00:29:37,760
signature

767
00:29:41,510 --> 00:29:39,520
those rocky silicates they're not

768
00:29:44,389 --> 00:29:41,520
conductive enough to explain

769
00:29:47,830 --> 00:29:44,399
that induced magnetic field signature

770
00:29:50,630 --> 00:29:47,840
ice even ice doped with salts still not

771
00:29:53,269 --> 00:29:50,640
conductive enough the best explanation

772
00:29:57,029 --> 00:29:53,279
for the induced magnetic field signature

773
00:29:59,990 --> 00:29:57,039
is this salty liquid water ocean

774
00:30:01,750 --> 00:30:00,000
overlaying by an ice shell of a few to

775
00:30:05,190 --> 00:30:01,760
maybe 10 or 15

776
00:30:09,830 --> 00:30:06,789
and here

777
00:30:11,029 --> 00:30:09,840
is one of the highest resolution mosaics

778
00:30:13,269 --> 00:30:11,039
that we have

779
00:30:15,110 --> 00:30:13,279
of the surface of europa

780
00:30:17,669 --> 00:30:15,120
this is the airplane

781
00:30:19,269 --> 00:30:17,679
view if you were able to look out

782
00:30:21,990 --> 00:30:19,279
across europa

783
00:30:23,909 --> 00:30:22,000
these ice cliffs with dark material that

784
00:30:26,389 --> 00:30:23,919
we know very little about

785
00:30:27,590 --> 00:30:26,399
jutting up from below fractures

786
00:30:29,990 --> 00:30:27,600
that

787
00:30:32,070 --> 00:30:30,000
perhaps have formed recently

788
00:30:34,389 --> 00:30:32,080

or perhaps they formed tens of millions

789
00:30:37,430 --> 00:30:34,399
of years ago at this point in time we

790
00:30:39,909 --> 00:30:37,440
just don't know and we don't know if

791
00:30:41,510 --> 00:30:39,919
some of this dark material is coming up

792
00:30:43,669 --> 00:30:41,520
from the ocean below

793
00:30:46,149 --> 00:30:43,679
if it tells us about the oceanic

794
00:30:47,029 --> 00:30:46,159
composition if it tells us

795
00:30:48,630 --> 00:30:47,039
about

796
00:30:50,470 --> 00:30:48,640
life forms living

797
00:30:53,590 --> 00:30:50,480
in that ocean below

798
00:30:55,190 --> 00:30:53,600
the galileo spacecraft left us with just

799
00:30:57,430 --> 00:30:55,200
enough information

800
00:30:59,509 --> 00:30:57,440
to feel confident about the presence of

801
00:31:01,590 --> 00:30:59,519
this global liquid water ocean

802
00:31:03,590 --> 00:31:01,600
but not enough information to know

803
00:31:06,870 --> 00:31:03,600
whether or not that ocean is in fact

804
00:31:11,029 --> 00:31:08,870
and that brings us back to earth and

805
00:31:13,190 --> 00:31:11,039
trying to understand some of these

806
00:31:14,549 --> 00:31:13,200
parameters some of the the constraints

807
00:31:17,990 --> 00:31:14,559
that we can place

808
00:31:20,630 --> 00:31:18,000
on habitability for life as we know it

809
00:31:22,389 --> 00:31:20,640
and life on earth is our guide for what

810
00:31:24,070 --> 00:31:22,399
it takes for a world to be habitable as

811
00:31:26,149 --> 00:31:24,080
i mentioned you need liquid water you

812
00:31:28,310 --> 00:31:26,159
need the elements for life and you need

813
00:31:30,710 --> 00:31:28,320

some form of energy

814
00:31:33,590 --> 00:31:30,720
and so what i'd like to do next is give

815
00:31:34,710 --> 00:31:33,600
you four short stories

816
00:31:38,230 --> 00:31:34,720
about

817
00:31:39,590 --> 00:31:38,240
life in extreme environments on earth

818
00:31:42,230 --> 00:31:39,600
first

819
00:31:43,830 --> 00:31:42,240
life in the cold then life in the deep

820
00:31:44,950 --> 00:31:43,840
and we'll work our way from the surface

821
00:31:49,110 --> 00:31:44,960
of the earth

822
00:31:51,669 --> 00:31:49,120
down to the deepest depths of our ocean

823
00:31:54,310 --> 00:31:51,679
the coldest place on earth is no

824
00:31:57,509 --> 00:31:54,320
challenge for life as we know it this is

825
00:32:03,190 --> 00:31:57,519
the dry valleys of antarctica

826
00:32:03,990 --> 00:32:03,200
we were working there back in in 2005

827
00:32:05,750 --> 00:32:04,000
this

828
00:32:07,830 --> 00:32:05,760
is a particular area called battleship

829
00:32:10,230 --> 00:32:07,840
promontory named in part because the

830
00:32:11,990 --> 00:32:10,240
early navy pilots who flew through there

831
00:32:15,350 --> 00:32:12,000
thought that that geological feature

832
00:32:16,870 --> 00:32:15,360
looked like a navy battleship

833
00:32:19,750 --> 00:32:16,880
we were there testing out

834
00:32:22,070 --> 00:32:19,760
instrumentation and studying life in the

835
00:32:24,549 --> 00:32:22,080
rocks of course around the perimeter of

836
00:32:26,070 --> 00:32:24,559
of antarctica there are penguins there

837
00:32:28,310 --> 00:32:26,080
are there are seals there are all sorts

838
00:32:29,669 --> 00:32:28,320

of other creatures but in the interior

839
00:32:31,750 --> 00:32:29,679
of antarctica

840
00:32:34,470 --> 00:32:31,760
there's no life except these tiniest of

841
00:32:36,149 --> 00:32:34,480
microbes that live in the rocks and some

842
00:32:39,190 --> 00:32:36,159
microbes which we think might live in

843
00:32:41,269 --> 00:32:39,200
the sub-glacial lakes

844
00:32:42,470 --> 00:32:41,279
so the reds the oranges the yellows that

845
00:32:46,070 --> 00:32:42,480
you see there

846
00:32:48,230 --> 00:32:46,080
those that patina is all caused by life

847
00:32:49,430 --> 00:32:48,240
living within the pore spaces of the

848
00:32:51,830 --> 00:32:49,440
rocks

849
00:32:53,269 --> 00:32:51,840
this gives you a nice view of

850
00:32:55,669 --> 00:32:53,279
one of these valleys now this is a bit

851
00:32:57,750 --> 00:32:55,679
deceiving here the

852
00:33:00,710 --> 00:32:57,760
it looks like this

853
00:33:02,470 --> 00:33:00,720
slope goes out into that valley but uh

854
00:33:04,549 --> 00:33:02,480
really if you were to walk

855
00:33:06,310 --> 00:33:04,559
uh to the edge there and look over this

856
00:33:08,710 --> 00:33:06,320
is what you would see

857
00:33:10,870 --> 00:33:08,720
this vast cliff

858
00:33:13,430 --> 00:33:10,880
and so here again those colors that you

859
00:33:16,070 --> 00:33:13,440
see those are all evidence of of life

860
00:33:17,830 --> 00:33:16,080
within in the rocks surviving keep in

861
00:33:20,230 --> 00:33:17,840
mind that antarctica is dark for half of

862
00:33:23,110 --> 00:33:20,240
the year it's incredibly cold incredibly

863
00:33:25,029 --> 00:33:23,120

dry and yet what life is doing

864
00:33:27,029 --> 00:33:25,039
is

865
00:33:30,149 --> 00:33:27,039
eking out a living in the tiniest of

866
00:33:33,029 --> 00:33:30,159
pore spaces between the sandstone grains

867
00:33:36,149 --> 00:33:33,039
so it seeks refuge it seeks shelter in

868
00:33:38,950 --> 00:33:36,159
those poor spaces and manages to use the

869
00:33:41,350 --> 00:33:38,960
available sunlight for part of the year

870
00:33:43,190 --> 00:33:41,360
and some of the water that that melts on

871
00:33:45,669 --> 00:33:43,200
occasion during the summer to then

872
00:33:47,590 --> 00:33:45,679
metabolize and grow and reproduce and to

873
00:33:49,029 --> 00:33:47,600
do photosynthesis

874
00:33:51,909 --> 00:33:49,039
and part of what we're doing is

875
00:33:53,990 --> 00:33:51,919
developing instrumentation to study

876
00:33:57,430 --> 00:33:54,000
these cryptoendolithic microbial

877
00:34:00,070 --> 00:33:57,440
communities that manage to to thrive

878
00:34:02,470 --> 00:34:00,080
just beneath the surface

879
00:34:04,389 --> 00:34:02,480
beneath that protected veneer

880
00:34:07,830 --> 00:34:04,399
of these sandstone rocks

881
00:34:10,470 --> 00:34:07,840
so in the coldest place on earth

882
00:34:13,990 --> 00:34:10,480
life has no problem

883
00:34:15,909 --> 00:34:14,000
but let's go to some place that is cold

884
00:34:18,710 --> 00:34:15,919
uh and dark

885
00:34:20,389 --> 00:34:18,720
and and wet um

886
00:34:21,909 --> 00:34:20,399
and a place where

887
00:34:24,389 --> 00:34:21,919
um

888
00:34:26,470 --> 00:34:24,399

that gets to be a little bit closer to

889
00:34:28,389 --> 00:34:26,480
the situation that we might find on

890
00:34:31,270 --> 00:34:28,399
europa

891
00:34:33,030 --> 00:34:31,280
to do this we'll travel up to alaska

892
00:34:34,389 --> 00:34:33,040
some of this work was recently featured

893
00:34:37,030 --> 00:34:34,399
in national geographic

894
00:34:40,550 --> 00:34:37,040
and it involves studying

895
00:34:43,109 --> 00:34:40,560
these some 10 000 permafrost lakes

896
00:34:44,950 --> 00:34:43,119
that are along the north slope of alaska

897
00:34:46,550 --> 00:34:44,960
these little dots here

898
00:34:47,430 --> 00:34:46,560
are lakes that are open during the

899
00:34:49,190 --> 00:34:47,440
summer

900
00:34:50,069 --> 00:34:49,200
and then freeze over

901
00:34:52,790 --> 00:34:50,079
in

902
00:34:55,270 --> 00:34:52,800
the october november time frame and some

903
00:34:57,270 --> 00:34:55,280
fraction of these lakes have methane

904
00:34:59,270 --> 00:34:57,280
bubbling out of them

905
00:35:00,470 --> 00:34:59,280
we know it's methane because the methane

906
00:35:03,109 --> 00:35:00,480
gets trapped in the ice and we can

907
00:35:05,750 --> 00:35:03,119
actually crack open the ice and light

908
00:35:10,150 --> 00:35:05,760
some of that methane on fire

909
00:35:13,589 --> 00:35:11,750
now

910
00:35:14,870 --> 00:35:13,599
tonight i don't have time to go into a

911
00:35:17,589 --> 00:35:14,880
lot of detail

912
00:35:19,510 --> 00:35:17,599
about the the biological work that we're

913
00:35:21,349 --> 00:35:19,520

doing doing on studying the microbes

914
00:35:23,270 --> 00:35:21,359
that are utilizing some of the methane

915
00:35:25,589 --> 00:35:23,280
and the microbes that are that are

916
00:35:28,150 --> 00:35:25,599
producing some of the methane i want to

917
00:35:30,630 --> 00:35:28,160
skip to some of the the technological

918
00:35:32,790 --> 00:35:30,640
development that we're doing

919
00:35:34,150 --> 00:35:32,800
to then study and monitor these

920
00:35:36,310 --> 00:35:34,160
ecosystems

921
00:35:38,790 --> 00:35:36,320
throughout the season

922
00:35:40,310 --> 00:35:38,800
we can only as humans we're fragile and

923
00:35:41,589 --> 00:35:40,320
we can only be up there for part of the

924
00:35:42,790 --> 00:35:41,599
year

925
00:35:44,950 --> 00:35:42,800
but of course

926
00:35:47,589 --> 00:35:44,960
here at jpl we build robots that go to

927
00:35:49,829 --> 00:35:47,599
much harsher environments than than

928
00:35:51,990 --> 00:35:49,839
than the north slope of alaska why can't

929
00:35:54,870 --> 00:35:52,000
we build something that we can just

930
00:35:56,310 --> 00:35:54,880
set free and deploy to study these lakes

931
00:35:59,430 --> 00:35:56,320
autonomously

932
00:36:00,310 --> 00:35:59,440
for months to years on end

933
00:36:04,310 --> 00:36:00,320
and

934
00:36:06,630 --> 00:36:04,320
to that uh to that effect um some of

935
00:36:08,550 --> 00:36:06,640
jpl's engineers john lichty and andy

936
00:36:10,870 --> 00:36:08,560
klesch and dan barrisford i think might

937
00:36:13,190 --> 00:36:10,880
be in the audience a brilliant team of

938
00:36:14,710 --> 00:36:13,200

engineers we're we're up there studying

939
00:36:16,069 --> 00:36:14,720
these lakes and and we're trying to

940
00:36:17,589 --> 00:36:16,079
figure out some of the chemistry of the

941
00:36:20,310 --> 00:36:17,599
ice water interface

942
00:36:22,310 --> 00:36:20,320
and what microbes are are utilizing the

943
00:36:24,069 --> 00:36:22,320
methane

944
00:36:26,950 --> 00:36:24,079
and to do that

945
00:36:28,550 --> 00:36:26,960
we wanted a vehicle a submersible

946
00:36:30,950 --> 00:36:28,560
that um

947
00:36:34,550 --> 00:36:30,960
that did not disturb the water too much

948
00:36:36,310 --> 00:36:34,560
and that could have a very long lifetime

949
00:36:37,349 --> 00:36:36,320
and we sort of had this collective aha

950
00:36:39,510 --> 00:36:37,359
of well

951
00:36:41,589 --> 00:36:39,520
a traditional submersible is very energy

952
00:36:43,190 --> 00:36:41,599
intensive because it's moving in three

953
00:36:45,589 --> 00:36:43,200
dimensions

954
00:36:47,670 --> 00:36:45,599
whereas a rover is quite efficient

955
00:36:50,470 --> 00:36:47,680
because when you get to a place you like

956
00:36:52,710 --> 00:36:50,480
you can just stop and do the science

957
00:36:54,550 --> 00:36:52,720
well why not just take a rover and turn

958
00:36:56,069 --> 00:36:54,560
it upside down

959
00:36:57,910 --> 00:36:56,079
and pretend

960
00:36:58,950 --> 00:36:57,920
like we're crawling on the underside of

961
00:37:01,030 --> 00:36:58,960
the ice

962
00:37:02,790 --> 00:37:01,040
and so that's exactly what our team

963
00:37:05,349 --> 00:37:02,800

designed we call it the buoyant rover

964
00:37:09,190 --> 00:37:05,359
for under ice exploration

965
00:37:11,109 --> 00:37:09,200
and along with doing this this uh uh

966
00:37:13,349 --> 00:37:11,119
interesting mobility innovation of

967
00:37:15,349 --> 00:37:13,359
roving of having buoyancy

968
00:37:18,150 --> 00:37:15,359
stick us to the underside of the ice

969
00:37:19,829 --> 00:37:18,160
this past field season i also set forth

970
00:37:25,109 --> 00:37:19,839
the challenge to our team

971
00:37:26,710 --> 00:37:25,119
to allow us to do europa-like operations

972
00:37:28,870 --> 00:37:26,720
now of course the first

973
00:37:30,870 --> 00:37:28,880
step in doing a spacecraft observation

974
00:37:31,910 --> 00:37:30,880
operation is you've got to survive

975
00:37:36,790 --> 00:37:31,920
launch

976
00:37:38,630 --> 00:37:36,800
analogous to uh to being trailed behind

977
00:37:40,790 --> 00:37:38,640
a snow machine on the alaskan permafrost

978
00:37:45,430 --> 00:37:40,800
for about 20 kilometers

979
00:37:49,190 --> 00:37:47,430
coupled with that we wanted a very small

980
00:37:51,270 --> 00:37:49,200
system something that we could could fit

981
00:37:53,030 --> 00:37:51,280
on the back of a of a sled

982
00:37:54,550 --> 00:37:53,040
here we're doing initial deployment and

983
00:37:56,950 --> 00:37:54,560
checkout here's john

984
00:37:58,790 --> 00:37:56,960
you can see that we're on a tether right

985
00:38:01,030 --> 00:37:58,800
now

986
00:38:03,589 --> 00:38:01,040
and what we're eventually building up to

987
00:38:04,470 --> 00:38:03,599
that i'll show you in in a few moments

988
00:38:06,069 --> 00:38:04,480

is

989
00:38:08,550 --> 00:38:06,079
pulling that tether

990
00:38:11,990 --> 00:38:08,560
and operating the vehicle

991
00:38:14,069 --> 00:38:12,000
untethered underwater under ice

992
00:38:15,990 --> 00:38:14,079
via satellite link

993
00:38:18,870 --> 00:38:16,000
such that we could leave it there and go

994
00:38:22,150 --> 00:38:18,880
back to our nice warm quanza hut and and

995
00:38:26,310 --> 00:38:24,950
in short sleeves uh here's

996
00:38:29,349 --> 00:38:26,320
one of the lakes that's got a lot of

997
00:38:31,109 --> 00:38:29,359
methane bubbling out of it

998
00:38:32,790 --> 00:38:31,119
andy clash here is poking through the

999
00:38:33,829 --> 00:38:32,800
ice trying to make sure it's safe to

1000
00:38:36,390 --> 00:38:33,839
walk on

1001
00:38:38,150 --> 00:38:36,400
and we'll pan over to a few of the

1002
00:38:40,310 --> 00:38:38,160
open regions

1003
00:38:42,710 --> 00:38:40,320
that still have methane bubbling out of

1004
00:38:44,390 --> 00:38:42,720
them and as you see as we pan further

1005
00:38:47,109 --> 00:38:44,400
and further to the right

1006
00:38:49,510 --> 00:38:47,119
i'm actually standing on pretty thin ice

1007
00:38:51,589 --> 00:38:49,520
um and i've actually taken a dip into

1008
00:38:52,710 --> 00:38:51,599
this water not intentionally

1009
00:38:55,829 --> 00:38:52,720
um

1010
00:38:57,430 --> 00:38:55,839
and uh uh it's cold but we we come

1011
00:39:00,069 --> 00:38:57,440
prepared and we've got lots of backup

1012
00:39:01,910 --> 00:39:00,079
gear so you can see that the methane is

1013
00:39:03,750 --> 00:39:01,920

actively bubbling out

1014
00:39:05,829 --> 00:39:03,760
it's not hot it's just the kinetic

1015
00:39:07,109 --> 00:39:05,839
activity of the methane that maintains

1016
00:39:09,589 --> 00:39:07,119
the open water

1017
00:39:10,870 --> 00:39:09,599
and now we'll dive under the ice

1018
00:39:13,670 --> 00:39:10,880
and this time

1019
00:39:17,349 --> 00:39:13,680
the rover is operating untethered

1020
00:39:21,510 --> 00:39:19,829
and the bubbles that you see coming out

1021
00:39:24,390 --> 00:39:21,520
those are methane bubbles and the

1022
00:39:25,430 --> 00:39:24,400
bubbles that are trapped in the ice

1023
00:39:28,470 --> 00:39:25,440
are

1024
00:39:29,910 --> 00:39:28,480
that's methane that that's being

1025
00:39:31,910 --> 00:39:29,920
encapsulated

1026
00:39:33,990 --> 00:39:31,920
in the ice as the ice thickens

1027
00:39:36,630 --> 00:39:34,000
throughout the the season

1028
00:39:39,270 --> 00:39:36,640
and so we've just begun to uh to make

1029
00:39:41,430 --> 00:39:39,280
this a platform that can survive for

1030
00:39:44,470 --> 00:39:41,440
long periods of time under the ice this

1031
00:39:45,270 --> 00:39:44,480
past field season we left it out there

1032
00:39:47,829 --> 00:39:45,280
for

1033
00:39:49,990 --> 00:39:47,839
two periods of about 30 hours

1034
00:39:51,829 --> 00:39:50,000
and john and andy and dan were able to

1035
00:39:52,790 --> 00:39:51,839
actually hand over control

1036
00:39:56,950 --> 00:39:52,800
to

1037
00:39:58,630 --> 00:39:56,960
via satellite link while it was under

1038
00:40:00,870 --> 00:39:58,640

the ice

1039
00:40:02,870 --> 00:40:00,880
this is what the rover sees

1040
00:40:03,990 --> 00:40:02,880
we'll take a dive

1041
00:40:07,670 --> 00:40:04,000
uh

1042
00:40:09,270 --> 00:40:07,680
into the lake this is an alaskan sunrise

1043
00:40:12,150 --> 00:40:09,280
the sun doesn't get much higher in the

1044
00:40:12,160 --> 00:40:16,710
we'll go over the little hole here

1045
00:40:16,720 --> 00:40:24,309
and i think you can hear it

1046
00:40:27,270 --> 00:40:25,190
in

1047
00:40:29,109 --> 00:40:27,280
and there you can see the uh

1048
00:40:31,030 --> 00:40:29,119
the rover vision

1049
00:40:32,710 --> 00:40:31,040
that allows us to examine the

1050
00:40:35,670 --> 00:40:32,720
the lake floor

1051
00:40:36,630 --> 00:40:35,680
and uh the ice water interface

1052
00:40:38,870 --> 00:40:36,640
and so

1053
00:40:41,750 --> 00:40:38,880
when we get to a spot that we then want

1054
00:40:43,270 --> 00:40:41,760
to do sampling and scientific analyses

1055
00:40:45,910 --> 00:40:43,280
we can leave the rover there without

1056
00:40:48,550 --> 00:40:45,920
expending excess battery power

1057
00:40:50,630 --> 00:40:48,560
and that potentially means that we can

1058
00:40:56,550 --> 00:40:50,640
leave it out there for a full winter

1059
00:40:59,910 --> 00:40:58,630
and as i mentioned we were able to to uh

1060
00:41:02,230 --> 00:40:59,920
to operate it

1061
00:41:03,990 --> 00:41:02,240
both from the kwanzaa hut and from jpl

1062
00:41:05,750 --> 00:41:04,000
now what i showed you it looked like fun

1063
00:41:07,430 --> 00:41:05,760

it looked nice and everything just to

1064
00:41:09,109 --> 00:41:07,440
emphasize uh um

1065
00:41:10,150 --> 00:41:09,119
there are many days that are not fun up

1066
00:41:11,349 --> 00:41:10,160
there

1067
00:41:13,190 --> 00:41:11,359
and in fact

1068
00:41:15,349 --> 00:41:13,200
on the the second deployment of our

1069
00:41:18,069 --> 00:41:15,359
rover we went out there and a huge storm

1070
00:41:19,589 --> 00:41:18,079
had rolled in it had blown down one of

1071
00:41:21,510 --> 00:41:19,599
our tents

1072
00:41:23,430 --> 00:41:21,520
and recovering the rover actually turned

1073
00:41:26,069 --> 00:41:23,440
out to be a bit of a challenge

1074
00:41:27,589 --> 00:41:26,079
because so much snow had had filled in

1075
00:41:29,030 --> 00:41:27,599
over the ice but eventually we were able

1076
00:41:31,030 --> 00:41:29,040
to get it out

1077
00:41:33,109 --> 00:41:31,040
and a national geographic photographer

1078
00:41:34,870 --> 00:41:33,119
mark thiessen was up there with us and

1079
00:41:38,069 --> 00:41:34,880
captured these beautiful images with a

1080
00:41:38,950 --> 00:41:38,079
with a camera on a stick uh showing

1081
00:41:41,030 --> 00:41:38,960
um

1082
00:41:42,790 --> 00:41:41,040
the rover in action

1083
00:41:46,390 --> 00:41:42,800
so we've gone to some place cold we've

1084
00:41:48,870 --> 00:41:46,400
gone to some place cold and wet and dark

1085
00:41:50,550 --> 00:41:48,880
next i'd like to bring you to

1086
00:41:53,510 --> 00:41:50,560
deep places

1087
00:41:54,710 --> 00:41:53,520
in our ocean places that are comparable

1088
00:41:58,630 --> 00:41:54,720

in pressure

1089
00:42:02,870 --> 00:41:58,640
to uh the the pressures that life within

1090
00:42:04,790 --> 00:42:02,880
a an ocean of europa might experience

1091
00:42:07,990 --> 00:42:04,800
and i was fortunate enough to be a part

1092
00:42:09,750 --> 00:42:08,000
of an expedition out to both the

1093
00:42:10,630 --> 00:42:09,760
mid-atlantic ridge and the east pacific

1094
00:42:13,190 --> 00:42:10,640
rise

1095
00:42:14,870 --> 00:42:13,200
to explore hydrothermal vents this was a

1096
00:42:17,190 --> 00:42:14,880
part of an imax

1097
00:42:19,430 --> 00:42:17,200
project spearheaded by james cameron in

1098
00:42:23,589 --> 00:42:19,440
disney we're on the russian research

1099
00:42:25,270 --> 00:42:23,599
vessel vessel the kaldish which has two

1100
00:42:27,109 --> 00:42:25,280
deep ocean submersibles that can each

1101
00:42:29,030 --> 00:42:27,119
carry three people

1102
00:42:31,190 --> 00:42:29,040
and these can go

1103
00:42:32,550 --> 00:42:31,200
to nearly six kilometers or more in

1104
00:42:34,870 --> 00:42:32,560
depth

1105
00:42:36,550 --> 00:42:34,880
i got to make a number of dives

1106
00:42:37,670 --> 00:42:36,560
and in some cases

1107
00:42:40,309 --> 00:42:37,680
we had

1108
00:42:41,829 --> 00:42:40,319
an additional acrylic sphere

1109
00:42:44,069 --> 00:42:41,839
rover with us we actually had two of

1110
00:42:45,430 --> 00:42:44,079
these and we made dives on some of these

1111
00:42:48,390 --> 00:42:45,440
sites with

1112
00:42:50,069 --> 00:42:48,400
two three and even four submersibles at

1113
00:42:50,870 --> 00:42:50,079

a time

1114
00:42:53,190 --> 00:42:50,880
and

1115
00:42:55,670 --> 00:42:53,200
part of what we are studying are these

1116
00:42:56,710 --> 00:42:55,680
hydrothermal vent ecosystems ecosystems

1117
00:42:59,910 --> 00:42:56,720
on earth

1118
00:43:01,750 --> 00:42:59,920
that revolutionized our understanding of

1119
00:43:03,829 --> 00:43:01,760
the habitability of our own planet these

1120
00:43:05,990 --> 00:43:03,839
were discovered back in the spring of

1121
00:43:08,550 --> 00:43:06,000
1977 not long

1122
00:43:09,670 --> 00:43:08,560
after viking had set down on the surface

1123
00:43:12,550 --> 00:43:09,680
of mars

1124
00:43:13,990 --> 00:43:12,560
no one really expected that these

1125
00:43:16,309 --> 00:43:14,000
hydrothermal vent

1126
00:43:18,390 --> 00:43:16,319
systems would be anything more than

1127
00:43:21,270 --> 00:43:18,400
geological curiosities

1128
00:43:23,030 --> 00:43:21,280
but in fact they turned out to be

1129
00:43:25,190 --> 00:43:23,040
oases for life

1130
00:43:27,430 --> 00:43:25,200
they were not just

1131
00:43:28,309 --> 00:43:27,440
regions where microbes were eking out a

1132
00:43:30,069 --> 00:43:28,319
living

1133
00:43:33,589 --> 00:43:30,079
there were places where

1134
00:43:36,390 --> 00:43:33,599
microbes utilizing chemosynthesis

1135
00:43:38,309 --> 00:43:36,400
formed the foundation of a complex food

1136
00:43:39,510 --> 00:43:38,319
chain consisting

1137
00:43:43,109 --> 00:43:39,520
of

1138
00:43:45,829 --> 00:43:43,119

shrimp and tube worms and and mussels uh

1139
00:43:47,589 --> 00:43:45,839
and crabs and so here all of the white

1140
00:43:50,309 --> 00:43:47,599
material that you're seeing

1141
00:43:52,630 --> 00:43:50,319
those are microbes that are utilizing

1142
00:43:55,510 --> 00:43:52,640
the chemistry of the hydrothermal vents

1143
00:43:56,630 --> 00:43:55,520
to do this process of chemosynthesis

1144
00:43:58,550 --> 00:43:56,640
functioning

1145
00:44:00,950 --> 00:43:58,560
with that chemosynthetic metabolic

1146
00:44:03,510 --> 00:44:00,960
pathway as opposed to photosynthesis

1147
00:44:06,309 --> 00:44:03,520
which of course requires the sun

1148
00:44:08,550 --> 00:44:06,319
but a site like this

1149
00:44:09,349 --> 00:44:08,560
requires active

1150
00:44:12,230 --> 00:44:09,359
um

1151
00:44:15,910 --> 00:44:12,240
creation of new seafloor we also went to

1152
00:44:18,790 --> 00:44:15,920
a region known as lost city shown here

1153
00:44:20,309 --> 00:44:18,800
this is a region that is off axis from

1154
00:44:21,430 --> 00:44:20,319
the spreading centers

1155
00:44:26,309 --> 00:44:21,440
and

1156
00:44:27,190 --> 00:44:26,319
particular type of hydrothermal vent

1157
00:44:29,349 --> 00:44:27,200
is that

1158
00:44:32,390 --> 00:44:29,359
it's not powered

1159
00:44:35,349 --> 00:44:32,400
by heat transferred from the mantle it's

1160
00:44:37,270 --> 00:44:35,359
powered by an exothermic reaction called

1161
00:44:39,589 --> 00:44:37,280
serpentinization

1162
00:44:43,349 --> 00:44:39,599
wherein

1163
00:44:46,710 --> 00:44:43,359

ultramafic rock rock from the mantle

1164
00:44:48,550 --> 00:44:46,720
is exposed to ocean water and drives a

1165
00:44:51,030 --> 00:44:48,560
chemical reaction

1166
00:44:53,030 --> 00:44:51,040
that's exothermic i.e sort of similar to

1167
00:44:56,790 --> 00:44:53,040
like taking a hand warmer and shaking it

1168
00:44:57,829 --> 00:44:56,800
up and that leads to this this diffuse

1169
00:44:59,589 --> 00:44:57,839
venting

1170
00:45:02,470 --> 00:44:59,599
and precipitation of things like

1171
00:45:04,230 --> 00:45:02,480
carbonate and it's around these sites

1172
00:45:06,230 --> 00:45:04,240
though it doesn't look quite as

1173
00:45:07,750 --> 00:45:06,240
biologically active there are many

1174
00:45:08,870 --> 00:45:07,760
microbial mats

1175
00:45:10,230 --> 00:45:08,880
um

1176
00:45:12,710 --> 00:45:10,240
thriving here

1177
00:45:14,550 --> 00:45:12,720
and one of the most profound creatures

1178
00:45:17,589 --> 00:45:14,560
that that i've ever seen on on our

1179
00:45:19,589 --> 00:45:17,599
planet this creature

1180
00:45:21,349 --> 00:45:19,599
large tenoforce spanning about a meter

1181
00:45:24,230 --> 00:45:21,359
and a half to two meters

1182
00:45:26,630 --> 00:45:24,240
this creature was just swimming around

1183
00:45:28,309 --> 00:45:26,640
that chimney that i just showed you

1184
00:45:29,109 --> 00:45:28,319
and an interesting little little story

1185
00:45:30,390 --> 00:45:29,119
here

1186
00:45:32,550 --> 00:45:30,400
um

1187
00:45:36,069 --> 00:45:32,560
the uh

1188
00:45:41,109 --> 00:45:38,630

i went down on this dive in one of those

1189
00:45:43,270 --> 00:45:41,119
those acrylic spheres

1190
00:45:44,150 --> 00:45:43,280
and got down to the bottom of the ocean

1191
00:45:46,550 --> 00:45:44,160
um

1192
00:45:47,910 --> 00:45:46,560
and started to collect some samples

1193
00:45:48,870 --> 00:45:47,920
and we're communicating with the other

1194
00:45:50,710 --> 00:45:48,880
subs

1195
00:45:52,470 --> 00:45:50,720
and james cameron was in the other

1196
00:45:54,390 --> 00:45:52,480
acrylic sphere

1197
00:45:56,069 --> 00:45:54,400
and they had not caught up with us so so

1198
00:45:57,190 --> 00:45:56,079
we radioed up to them and we said well

1199
00:46:04,710 --> 00:45:57,200
what's

1200
00:46:05,510 --> 00:46:04,720
uh we acoustically transponded uh to to

1201
00:46:07,589 --> 00:46:05,520
uh

1202
00:46:09,750 --> 00:46:07,599
to the other submersible and it's a real

1203
00:46:10,870 --> 00:46:09,760
choppy communication uh so it's hard to

1204
00:46:13,109 --> 00:46:10,880
make things out

1205
00:46:15,270 --> 00:46:13,119
but we get uh a communication back

1206
00:46:17,030 --> 00:46:15,280
saying oh yeah yeah we're we've run into

1207
00:46:18,630 --> 00:46:17,040
a little bit of trouble uh don't worry

1208
00:46:20,230 --> 00:46:18,640
we'll be down there at the bottom of the

1209
00:46:21,190 --> 00:46:20,240
ocean in five minutes

1210
00:46:22,870 --> 00:46:21,200
so

1211
00:46:24,550 --> 00:46:22,880
we keep on sampling and it's about that

1212
00:46:25,910 --> 00:46:24,560
time that i discovered this creature

1213
00:46:27,750 --> 00:46:25,920

because i was picking up a sample and i

1214
00:46:30,309 --> 00:46:27,760
turned the rover a little bit and there

1215
00:46:32,710 --> 00:46:30,319
was this this astonishing space bagel as

1216
00:46:35,750 --> 00:46:32,720
we first called it

1217
00:46:37,829 --> 00:46:35,760
and so we called back up to to uh

1218
00:46:39,510 --> 00:46:37,839
to cameron and to paul the the pilot

1219
00:46:40,790 --> 00:46:39,520
that was with him we said you guys gotta

1220
00:46:42,390 --> 00:46:40,800
gotta get down here you won't believe

1221
00:46:44,390 --> 00:46:42,400
what we're looking at

1222
00:46:48,390 --> 00:46:44,400
they said oh yeah we're we're coming uh

1223
00:46:50,710 --> 00:46:49,589
and uh

1224
00:46:54,309 --> 00:46:50,720
and of course the last thing that you

1225
00:46:55,349 --> 00:46:54,319
want to hear uh uh when from your your

1226
00:46:57,109 --> 00:46:55,359
friends and colleagues that are in a

1227
00:46:59,670 --> 00:46:57,119
submersible is that there's a leak in

1228
00:47:03,109 --> 00:47:01,270
and so we said are you sure you don't

1229
00:47:08,550 --> 00:47:03,119
want a surface and they said no no no we

1230
00:47:14,390 --> 00:47:12,630
now there actually is some logic to that

1231
00:47:16,950 --> 00:47:14,400
because the way that these submersibles

1232
00:47:17,990 --> 00:47:16,960
work these particular submersibles work

1233
00:47:19,670 --> 00:47:18,000
is that

1234
00:47:21,910 --> 00:47:19,680
you get in from below

1235
00:47:22,870 --> 00:47:21,920
and there's a cork like plug in the

1236
00:47:24,950 --> 00:47:22,880
bottom

1237
00:47:27,270 --> 00:47:24,960
and as you drop further down in the

1238
00:47:28,150 --> 00:47:27,280

ocean the pressure increases and the

1239
00:47:29,670 --> 00:47:28,160
force

1240
00:47:31,349 --> 00:47:29,680
pushing on that plug

1241
00:47:33,270 --> 00:47:31,359
creates a tighter and tighter tighter

1242
00:47:35,510 --> 00:47:33,280
seal and so they said yeah we'll just

1243
00:47:37,510 --> 00:47:35,520
keep on going down and that'll

1244
00:47:38,790 --> 00:47:37,520
improve the seal

1245
00:47:40,549 --> 00:47:38,800
and sure enough they got down to the

1246
00:47:43,750 --> 00:47:40,559
bottom

1247
00:47:45,670 --> 00:47:43,760
and the leak persisted

1248
00:47:46,950 --> 00:47:45,680
but but they didn't die

1249
00:47:48,790 --> 00:47:46,960
and

1250
00:47:50,470 --> 00:47:48,800
in fact

1251
00:47:53,109 --> 00:47:50,480
cameron was able to

1252
00:47:55,109 --> 00:47:53,119
recover this astonishing footage

1253
00:47:56,150 --> 00:47:55,119
of this creature in action

1254
00:47:58,150 --> 00:47:56,160
um

1255
00:48:00,470 --> 00:47:58,160
arguably one of the most bizarre and

1256
00:48:01,349 --> 00:48:00,480
beautiful life forms that that i've ever

1257
00:48:02,150 --> 00:48:01,359
had the

1258
00:48:05,190 --> 00:48:02,160
uh

1259
00:48:08,630 --> 00:48:05,200
the the um

1260
00:48:10,390 --> 00:48:08,640
uh a great chance to experience

1261
00:48:12,630 --> 00:48:10,400
but okay so these hydrothermal vents

1262
00:48:15,670 --> 00:48:12,640
these are great um but to be honest

1263
00:48:16,549 --> 00:48:15,680

they're not that europa-like um

1264
00:48:18,069 --> 00:48:16,559
this

1265
00:48:20,950 --> 00:48:18,079
the depths that were

1266
00:48:23,430 --> 00:48:20,960
that i've been showing you are three to

1267
00:48:25,589 --> 00:48:23,440
four kilometers uh lost cities at about

1268
00:48:27,829 --> 00:48:25,599
a kilometer depth

1269
00:48:30,950 --> 00:48:27,839
the pressures in these regions is

1270
00:48:31,990 --> 00:48:30,960
equivalent to maybe 10 to 20 kilometers

1271
00:48:34,630 --> 00:48:32,000
or so

1272
00:48:36,870 --> 00:48:34,640
perhaps as much as 30 kilometers below

1273
00:48:40,470 --> 00:48:36,880
the surface of europa and we think that

1274
00:48:42,470 --> 00:48:40,480
the sea floor of europa may well be 100

1275
00:48:44,069 --> 00:48:42,480
kilometers or so down

1276
00:48:46,230 --> 00:48:44,079
to get to

1277
00:48:47,190 --> 00:48:46,240
pressures comparable

1278
00:48:48,630 --> 00:48:47,200
to

1279
00:48:50,710 --> 00:48:48,640
those depths

1280
00:48:52,870 --> 00:48:50,720
you need to go

1281
00:48:55,990 --> 00:48:52,880
here to the mariana trench to the

1282
00:48:59,589 --> 00:48:56,000
challenger deep region of our ocean

1283
00:49:02,790 --> 00:48:59,599
a region where our ocean gets down to 11

1284
00:49:04,790 --> 00:49:02,800
kilometers and i um was part of an

1285
00:49:07,510 --> 00:49:04,800
expedition to go back out to the

1286
00:49:08,710 --> 00:49:07,520
challenger deep uh james cameron made

1287
00:49:10,870 --> 00:49:08,720
the dive

1288
00:49:13,430 --> 00:49:10,880

back to this deepest depth and we also

1289
00:49:15,349 --> 00:49:13,440
had a few robotic landers that that we

1290
00:49:17,589 --> 00:49:15,359
dropped along with the uh human

1291
00:49:19,670 --> 00:49:17,599
submersible

1292
00:49:21,430 --> 00:49:19,680
unlike the previous expedition i did not

1293
00:49:22,309 --> 00:49:21,440
get to go down to the bottom of mariana

1294
00:49:23,750 --> 00:49:22,319
trench

1295
00:49:28,710 --> 00:49:23,760
so when people ask me what it looked

1296
00:49:31,829 --> 00:49:30,790
pretty much like any other spot on the

1297
00:49:34,069 --> 00:49:31,839
ocean

1298
00:49:38,230 --> 00:49:34,079
uh and you may have seen lots of uh

1299
00:49:39,910 --> 00:49:38,240
pictures and and and video uh of uh

1300
00:49:42,950 --> 00:49:39,920
of this expedition

1301
00:49:43,990 --> 00:49:42,960
an incredible engineering achievement

1302
00:49:46,950 --> 00:49:44,000
this

1303
00:49:48,630 --> 00:49:46,960
the human submersible

1304
00:49:50,150 --> 00:49:48,640
is a vertical

1305
00:49:51,750 --> 00:49:50,160
dropping

1306
00:49:53,430 --> 00:49:51,760
torpedo

1307
00:49:55,190 --> 00:49:53,440
it goes in horizontally like this and

1308
00:49:56,630 --> 00:49:55,200
i'll show you in a few slides what it

1309
00:49:58,710 --> 00:49:56,640
looked like as it was dropping through

1310
00:49:59,990 --> 00:49:58,720
the ocean as i mentioned i didn't get to

1311
00:50:02,790 --> 00:50:00,000
get uh

1312
00:50:04,470 --> 00:50:02,800
go on a trip in it uh

1313
00:50:06,870 --> 00:50:04,480

james cameron was the only one that made

1314
00:50:10,950 --> 00:50:06,880
the dive to the bottom of the ocean uh

1315
00:50:13,430 --> 00:50:10,960
and uh and and quite a spectacular feat

1316
00:50:14,790 --> 00:50:13,440
the the integration and testing of this

1317
00:50:18,390 --> 00:50:14,800
submersible

1318
00:50:20,309 --> 00:50:18,400
took place in a time frame of months

1319
00:50:21,990 --> 00:50:20,319
cameron had been planning it and and had

1320
00:50:24,230 --> 00:50:22,000
a small core team

1321
00:50:25,349 --> 00:50:24,240
that made some of the key features over

1322
00:50:27,829 --> 00:50:25,359
the course of

1323
00:50:30,950 --> 00:50:27,839
of roughly five or so years

1324
00:50:34,150 --> 00:50:30,960
but really the integration and testing

1325
00:50:39,589 --> 00:50:37,829
roughly october to november of 2011

1326
00:50:42,710 --> 00:50:39,599
and the big dive

1327
00:50:45,109 --> 00:50:42,720
was done near the end of march in 2012.

1328
00:50:47,270 --> 00:50:45,119
um i won't go into it tonight but at

1329
00:50:49,510 --> 00:50:47,280
some point we'll have that team here to

1330
00:50:51,510 --> 00:50:49,520
talk about systems engineering

1331
00:50:56,230 --> 00:50:51,520
in a very tight time frame because uh it

1332
00:50:58,710 --> 00:50:57,829
the

1333
00:51:00,710 --> 00:50:58,720
so

1334
00:51:03,190 --> 00:51:00,720
cameron came back alive on on the human

1335
00:51:05,829 --> 00:51:03,200
exploration side uh that that was great

1336
00:51:07,829 --> 00:51:05,839
everybody breathed a huge sigh of relief

1337
00:51:09,829 --> 00:51:07,839
but a little bit of an anecdote for you

1338
00:51:11,030 --> 00:51:09,839

um

1339
00:51:14,150 --> 00:51:11,040
though

1340
00:51:16,549 --> 00:51:14,160
everything went off without a hitch

1341
00:51:18,069 --> 00:51:16,559
the team had planned on doing the big

1342
00:51:19,589 --> 00:51:18,079
dive

1343
00:51:21,990 --> 00:51:19,599
towards the end of january if not

1344
00:51:23,990 --> 00:51:22,000
january then certainly in february and

1345
00:51:25,670 --> 00:51:24,000
if not in february than sometime in in

1346
00:51:28,150 --> 00:51:25,680
early march

1347
00:51:31,349 --> 00:51:28,160
but with weather and a few things a few

1348
00:51:36,150 --> 00:51:34,150
those dates slipped and when we started

1349
00:51:39,030 --> 00:51:36,160
out the expedition

1350
00:51:40,150 --> 00:51:39,040
there was one date that cameron could

1351
00:51:41,589 --> 00:51:40,160
not

1352
00:51:44,710 --> 00:51:41,599
um

1353
00:51:47,349 --> 00:51:44,720
miss and that was that he had to be

1354
00:51:49,750 --> 00:51:47,359
in london walking the red carpet on i

1355
00:51:54,150 --> 00:51:49,760
think it was march 27th

1356
00:51:56,790 --> 00:51:54,160
for the re-release of titanic 3d

1357
00:51:58,390 --> 00:51:56,800
and this was this was some contract that

1358
00:51:59,990 --> 00:51:58,400
he had signed in blood that he would be

1359
00:52:02,950 --> 00:52:00,000
there

1360
00:52:04,470 --> 00:52:02,960
and lo and behold with uh with some of

1361
00:52:05,910 --> 00:52:04,480
the delays due to weather and other

1362
00:52:07,910 --> 00:52:05,920
things

1363
00:52:10,790 --> 00:52:07,920

we found ourselves

1364
00:52:15,270 --> 00:52:10,800
on sunday night march 25th

1365
00:52:20,950 --> 00:52:17,670
and jim had to be in london less than 48

1366
00:52:25,270 --> 00:52:23,750
but thankfully on monday morning the the

1367
00:52:28,950 --> 00:52:25,280
seas were calm

1368
00:52:31,270 --> 00:52:28,960
and we're able to to deploy the sub

1369
00:52:32,630 --> 00:52:31,280
it took about

1370
00:52:33,589 --> 00:52:32,640
less than four hours to get to the

1371
00:52:35,510 --> 00:52:33,599
bottom

1372
00:52:38,390 --> 00:52:35,520
the the torpedo just dropped straight

1373
00:52:39,349 --> 00:52:38,400
down he was then able to traverse

1374
00:52:41,030 --> 00:52:39,359
along

1375
00:52:42,870 --> 00:52:41,040
the challenger deep for a few hours and

1376
00:52:44,470 --> 00:52:42,880
then come back up

1377
00:52:47,030 --> 00:52:44,480
but of course

1378
00:52:48,870 --> 00:52:47,040
by that time it was late on monday and

1379
00:52:50,710 --> 00:52:48,880
he still had to get

1380
00:52:53,829 --> 00:52:50,720
to london

1381
00:52:55,910 --> 00:52:53,839
now this is where um

1382
00:52:57,430 --> 00:52:55,920
i started to appreciate

1383
00:53:00,390 --> 00:52:57,440
the

1384
00:53:03,510 --> 00:53:00,400
dividing line between um life as a

1385
00:53:05,430 --> 00:53:03,520
scientist and and and life as a

1386
00:53:08,470 --> 00:53:05,440
bazillionaire hollywood uh director

1387
00:53:09,990 --> 00:53:08,480
producer etc as if it hadn't been clear

1388
00:53:10,870 --> 00:53:10,000

before

1389
00:53:12,630 --> 00:53:10,880
uh

1390
00:53:14,309 --> 00:53:12,640
so we're all kind of like how how is how

1391
00:53:16,470 --> 00:53:14,319
is jim gonna going to make this this

1392
00:53:18,710 --> 00:53:16,480
trip when we got back out to the mariana

1393
00:53:20,710 --> 00:53:18,720
trench after doing some repairs we

1394
00:53:22,710 --> 00:53:20,720
noticed this ship on the horizon which

1395
00:53:23,910 --> 00:53:22,720
looked quite small at first but as we

1396
00:53:26,150 --> 00:53:23,920
got closer

1397
00:53:27,190 --> 00:53:26,160
we saw that in fact

1398
00:53:30,309 --> 00:53:27,200
it was a

1399
00:53:33,589 --> 00:53:31,670
and um

1400
00:53:35,030 --> 00:53:33,599
it turns out that this is paul allen's

1401
00:53:35,910 --> 00:53:35,040
yacht

1402
00:53:37,430 --> 00:53:35,920
and

1403
00:53:39,349 --> 00:53:37,440
apparently this is one of the fastest

1404
00:53:41,270 --> 00:53:39,359
yachts on the planet

1405
00:53:42,790 --> 00:53:41,280
and so

1406
00:53:43,750 --> 00:53:42,800
cameron needed to get from point a to

1407
00:53:46,390 --> 00:53:43,760
point b

1408
00:53:47,589 --> 00:53:46,400
and uh he was called up paul allen and

1409
00:53:49,670 --> 00:53:47,599
said hey paul i'm going to be making a

1410
00:53:51,510 --> 00:53:49,680
dive to the deepest depths of our ocean

1411
00:53:53,270 --> 00:53:51,520
want to come out check it out and then

1412
00:53:55,990 --> 00:53:53,280
and then help me get to guam where i can

1413
00:53:58,390 --> 00:53:56,000

catch a plane and head on from from guam

1414
00:54:00,309 --> 00:53:58,400
to uh through russia and on to london

1415
00:54:02,230 --> 00:54:00,319
uh and sure enough he made it to the red

1416
00:54:04,150 --> 00:54:02,240
carpet just in the nick of time

1417
00:54:07,670 --> 00:54:04,160
and uh paramount or whoever it was was

1418
00:54:11,510 --> 00:54:07,680
happy uh and and he lived you know the

1419
00:54:13,510 --> 00:54:11,520
the story had a happy ending now um

1420
00:54:15,750 --> 00:54:13,520
again just to be clear so that's the uh

1421
00:54:17,829 --> 00:54:15,760
that's the the yacht that paul allen had

1422
00:54:24,150 --> 00:54:17,839
and the the fancy hollywood stuff

1423
00:54:27,750 --> 00:54:26,309
a lovely little vessel called uh the

1424
00:54:29,030 --> 00:54:27,760
barracuda

1425
00:54:30,549 --> 00:54:29,040
um

1426
00:54:32,470 --> 00:54:30,559
and uh and

1427
00:54:34,549 --> 00:54:32,480
so it was it was a fine place to call

1428
00:54:36,870 --> 00:54:34,559
home for for for many weeks

1429
00:54:39,030 --> 00:54:36,880
uh just to show you the the

1430
00:54:40,390 --> 00:54:39,040
human submersible on the bottom

1431
00:54:42,870 --> 00:54:40,400
there it is and it's it's sort of

1432
00:54:45,829 --> 00:54:42,880
vertical position uh and what's taking

1433
00:54:48,150 --> 00:54:45,839
the picture in this particular image

1434
00:54:50,870 --> 00:54:48,160
are these robotic landers that were

1435
00:54:53,109 --> 00:54:50,880
built um down at scripps uh spearheaded

1436
00:54:53,990 --> 00:54:53,119
by kevin hardy a a wonderful engineer

1437
00:54:56,470 --> 00:54:54,000
down there

1438
00:54:58,710 --> 00:54:56,480

uh and and overseen by doug bartlett the

1439
00:55:01,910 --> 00:54:58,720
chief scientist of the expedition

1440
00:55:04,789 --> 00:55:01,920
and these are telephone booth size

1441
00:55:07,030 --> 00:55:04,799
vehicles that just drop down through the

1442
00:55:09,670 --> 00:55:07,040
ocean and when they get down there they

1443
00:55:11,430 --> 00:55:09,680
deploy that arm that you see on the side

1444
00:55:13,829 --> 00:55:11,440
in the in the middle picture

1445
00:55:15,510 --> 00:55:13,839
and that arm has got a water sampling

1446
00:55:18,710 --> 00:55:15,520
device and and there are cameras on

1447
00:55:22,390 --> 00:55:18,720
board uh and sediment cores and various

1448
00:55:24,069 --> 00:55:22,400
traps to to try and attract creatures

1449
00:55:25,349 --> 00:55:24,079
and so we deployed these on the

1450
00:55:27,030 --> 00:55:25,359
challenger deep and one of the great

1451
00:55:29,190 --> 00:55:27,040
advantages of these is that you can

1452
00:55:31,990 --> 00:55:29,200
leave them down there for a long time

1453
00:55:33,270 --> 00:55:32,000
and what i'm showing you here

1454
00:55:35,190 --> 00:55:33,280
is

1455
00:55:38,150 --> 00:55:35,200
video footage

1456
00:55:40,789 --> 00:55:38,160
from the deepest depths of our ocean the

1457
00:55:42,549 --> 00:55:40,799
challenger deep a depth of greater than

1458
00:55:44,870 --> 00:55:42,559
11 kilometers

1459
00:55:47,190 --> 00:55:44,880
and the this is the what you're seeing

1460
00:55:49,589 --> 00:55:47,200
in the foreground here is that robotic

1461
00:55:51,910 --> 00:55:49,599
arm the the water sampling device

1462
00:55:54,470 --> 00:55:51,920
and there's a fish head in the net there

1463
00:55:55,829 --> 00:55:54,480

and after several hours of just

1464
00:55:56,630 --> 00:55:55,839
observing

1465
00:55:58,870 --> 00:55:56,640
this

1466
00:56:02,549 --> 00:55:58,880
fish head trapped in the net

1467
00:56:05,030 --> 00:56:02,559
what we observed are all of these

1468
00:56:07,910 --> 00:56:05,040
shrimp-like amphipods

1469
00:56:11,030 --> 00:56:07,920
collecting around the trap feeding

1470
00:56:13,670 --> 00:56:11,040
on the bait that we had left there

1471
00:56:16,630 --> 00:56:13,680
and this is astonishing

1472
00:56:17,589 --> 00:56:16,640
not only is the deepest depth of our

1473
00:56:19,670 --> 00:56:17,599
ocean

1474
00:56:22,710 --> 00:56:19,680
a place where you might have simple life

1475
00:56:26,470 --> 00:56:22,720
forms but it's a place where complex

1476
00:56:29,030 --> 00:56:26,480
multicellular life forms like these

1477
00:56:30,710 --> 00:56:29,040
exist and thrive

1478
00:56:32,870 --> 00:56:30,720
taking a close-up look at these this

1479
00:56:35,430 --> 00:56:32,880
this is what they look like

1480
00:56:37,030 --> 00:56:35,440
not the prettiest of creatures

1481
00:56:38,470 --> 00:56:37,040
and somebody in the audience always

1482
00:56:39,670 --> 00:56:38,480
wants to know well what did they taste

1483
00:56:41,670 --> 00:56:39,680
like

1484
00:56:43,270 --> 00:56:41,680
uh and sure enough

1485
00:56:44,950 --> 00:56:43,280
one of the ship hands grabbed one of

1486
00:56:46,150 --> 00:56:44,960
these and popped it into his mouth and

1487
00:56:48,390 --> 00:56:46,160
ate it

1488
00:56:49,910 --> 00:56:48,400

and subsequently uh ran to the side of

1489
00:56:53,670 --> 00:56:49,920
the boat and

1490
00:56:57,109 --> 00:56:53,680
and returned the creature to the ocean

1491
00:57:00,390 --> 00:56:58,630
but okay so that that video from the

1492
00:57:02,309 --> 00:57:00,400
challenger deep uh astonishing these

1493
00:57:03,430 --> 00:57:02,319
these these complex creatures thriving

1494
00:57:06,150 --> 00:57:03,440
down there

1495
00:57:07,670 --> 00:57:06,160
but as i as i showed we we had a bait

1496
00:57:09,670 --> 00:57:07,680
trap out there and so those creatures

1497
00:57:11,589 --> 00:57:09,680
were attracted by that food

1498
00:57:13,589 --> 00:57:11,599
what do they eat when when there's no

1499
00:57:15,109 --> 00:57:13,599
fish head around what is driving that

1500
00:57:16,710 --> 00:57:15,119
ecosystem

1501
00:57:18,950 --> 00:57:16,720
we were not really able to answer that

1502
00:57:21,270 --> 00:57:18,960
question with with the uh the

1503
00:57:23,829 --> 00:57:21,280
drop in the challenge deep but when we

1504
00:57:26,630 --> 00:57:23,839
made a drop of the robotic landers in an

1505
00:57:28,549 --> 00:57:26,640
area just a little bit to the north east

1506
00:57:30,630 --> 00:57:28,559
of the of the challenger deep in a

1507
00:57:34,309 --> 00:57:30,640
region called the cyrena deep

1508
00:57:35,670 --> 00:57:34,319
we saw a uh quite a spectacular sight

1509
00:57:38,470 --> 00:57:35,680
in this video what you'll see is the

1510
00:57:41,750 --> 00:57:38,480
robotic arm drop

1511
00:57:43,349 --> 00:57:41,760
it'll hit the sea floor

1512
00:57:44,630 --> 00:57:43,359
and

1513
00:57:47,349 --> 00:57:44,640

dust up

1514
00:57:49,510 --> 00:57:47,359
a big old cloud and you can see

1515
00:57:53,750 --> 00:57:49,520
right away in the background there

1516
00:57:55,109 --> 00:57:53,760
is a geologist and scientists dream

1517
00:57:57,270 --> 00:57:55,119
outcrop

1518
00:57:58,870 --> 00:57:57,280
and those of you that have been part of

1519
00:58:01,109 --> 00:57:58,880
the part of the mars missions know of

1520
00:58:02,150 --> 00:58:01,119
course that scientists go crazy for

1521
00:58:03,990 --> 00:58:02,160
outcrop

1522
00:58:06,069 --> 00:58:04,000
because it actually gives us some

1523
00:58:09,270 --> 00:58:06,079
geological context for what's actually

1524
00:58:11,270 --> 00:58:09,280
going on in the environment and so when

1525
00:58:14,309 --> 00:58:11,280
we got the uh the footage back and we're

1526
00:58:16,710 --> 00:58:14,319
able to piece together the images

1527
00:58:19,109 --> 00:58:16,720
this is what we saw uh in all of the

1528
00:58:21,030 --> 00:58:19,119
other regions in the mariana trench

1529
00:58:23,109 --> 00:58:21,040
for the most part all that had been seen

1530
00:58:25,190 --> 00:58:23,119
are just these sediment beds

1531
00:58:27,750 --> 00:58:25,200
no actual

1532
00:58:30,309 --> 00:58:27,760
indigenous rocks that we could then

1533
00:58:32,789 --> 00:58:30,319
connect geochemistry to

1534
00:58:35,510 --> 00:58:32,799
and what astonished us even more is that

1535
00:58:36,950 --> 00:58:35,520
when you zoom in on these rocks to the

1536
00:58:39,190 --> 00:58:36,960
right there

1537
00:58:40,309 --> 00:58:39,200
this is what you see

1538
00:58:41,430 --> 00:58:40,319

yeah

1539
00:58:43,510 --> 00:58:41,440
uh

1540
00:58:45,190 --> 00:58:43,520
we're calling these the bearded rocks of

1541
00:58:46,230 --> 00:58:45,200
the cyrena deep

1542
00:58:48,829 --> 00:58:46,240
because

1543
00:58:51,510 --> 00:58:48,839
they they look like sort of a fuzzy

1544
00:58:53,990 --> 00:58:51,520
rock and our current

1545
00:58:56,309 --> 00:58:54,000
um hypothesis and and the evidence

1546
00:58:58,870 --> 00:58:56,319
supports this so far is that

1547
00:59:02,549 --> 00:58:58,880
these filaments coming off of these

1548
00:59:04,789 --> 00:59:02,559
rocks are microbial mats

1549
00:59:07,589 --> 00:59:04,799
that are metabolizing

1550
00:59:09,589 --> 00:59:07,599
fluids that are slowly percolating up

1551
00:59:14,069 --> 00:59:09,599
from the from the ocean floor

1552
00:59:14,870 --> 00:59:14,079
below and from those rocks uh utilizing

1553
00:59:17,109 --> 00:59:14,880
uh

1554
00:59:18,470 --> 00:59:17,119
the the effluent from this this process

1555
00:59:19,750 --> 00:59:18,480
of serpentinization that i mentioned

1556
00:59:22,789 --> 00:59:19,760
before

1557
00:59:25,589 --> 00:59:22,799
and so we think that in the deepest

1558
00:59:27,349 --> 00:59:25,599
region of our own ocean

1559
00:59:29,190 --> 00:59:27,359
this exothermic process of

1560
00:59:32,950 --> 00:59:29,200
serpentinization

1561
00:59:36,630 --> 00:59:32,960
is providing the chemical energy needed

1562
00:59:37,910 --> 00:59:36,640
to help sustain a microbial ecosystem

1563
00:59:40,069 --> 00:59:37,920

that is then

1564
00:59:41,910 --> 00:59:40,079
sustaining those complex creatures those

1565
00:59:42,870 --> 00:59:41,920
amphipods that i showed you in the

1566
00:59:44,870 --> 00:59:42,880
previous

1567
00:59:46,870 --> 00:59:44,880
video

1568
00:59:49,990 --> 00:59:46,880
which is

1569
00:59:51,750 --> 00:59:50,000
evidence of not just a simple ecosystem

1570
00:59:55,349 --> 00:59:51,760
in one of the the harshest environments

1571
00:59:58,309 --> 00:59:55,359
on earth but but a quite a complex and

1572
01:00:02,470 --> 00:59:58,319
involved ecosystem in the deepest depths

1573
01:00:03,750 --> 01:00:02,480
of our ocean in a region that is

1574
01:00:05,910 --> 01:00:03,760
as close

1575
01:00:07,829 --> 01:00:05,920
to europa's seafloor as we can get on

1576
01:00:09,829 --> 01:00:07,839
earth

1577
01:00:11,990 --> 01:00:09,839
so how does this all add up for what we

1578
01:00:12,950 --> 01:00:12,000
want to do on europa

1579
01:00:15,270 --> 01:00:12,960
well

1580
01:00:17,030 --> 01:00:15,280
i'll give you my dream of dreams

1581
01:00:19,510 --> 01:00:17,040
in the dream scenario

1582
01:00:21,750 --> 01:00:19,520
some decades from now

1583
01:00:23,829 --> 01:00:21,760
we will deploy some

1584
01:00:25,030 --> 01:00:23,839
highly capable lander

1585
01:00:27,589 --> 01:00:25,040
that

1586
01:00:28,950 --> 01:00:27,599
brilliant engineers at nasa and jpl are

1587
01:00:29,990 --> 01:00:28,960
able to design

1588
01:00:32,870 --> 01:00:30,000

that can

1589
01:00:35,990 --> 01:00:32,880
negotiate the

1590
01:00:38,150 --> 01:00:36,000
the surface of europa avoiding cliffs

1591
01:00:40,789 --> 01:00:38,160
and boulders

1592
01:00:44,470 --> 01:00:40,799
finding a nice

1593
01:00:47,430 --> 01:00:44,480
soft and and flat landing spot

1594
01:00:49,750 --> 01:00:47,440
deploying a melt probe with some sort of

1595
01:00:52,069 --> 01:00:49,760
uh heat source on the front end to to

1596
01:00:53,670 --> 01:00:52,079
melt through the ice

1597
01:00:55,510 --> 01:00:53,680
going all the way through that ice

1598
01:00:58,069 --> 01:00:55,520
leaving behind a fiber optic cure or

1599
01:01:00,150 --> 01:00:58,079
some other communication cable to to

1600
01:01:02,950 --> 01:01:00,160
send data back to the surface

1601
01:01:05,270 --> 01:01:02,960
it reaches the ocean

1602
01:01:07,829 --> 01:01:05,280
deploys that front end nose cone and out

1603
01:01:09,109 --> 01:01:07,839
pops this autonomous underwater vehicle

1604
01:01:11,030 --> 01:01:09,119
we're of course not going to be able to

1605
01:01:14,150 --> 01:01:11,040
joystick this from from earth so this

1606
01:01:15,750 --> 01:01:14,160
thing would have to be quite autonomous

1607
01:01:17,270 --> 01:01:15,760
it gets down to the bottom of the sea

1608
01:01:20,789 --> 01:01:17,280
floor

1609
01:01:22,230 --> 01:01:20,799
and at least in our imax hollywood

1610
01:01:25,430 --> 01:01:22,240
version

1611
01:01:27,670 --> 01:01:25,440
we then find not only hydrothermal vents

1612
01:01:30,150 --> 01:01:27,680
but happy creatures

1613
01:01:33,190 --> 01:01:30,160

uh that are delighted to see us

1614
01:01:35,910 --> 01:01:33,200
and we have revolutionized the uh

1615
01:01:38,710 --> 01:01:35,920
the science of biology

1616
01:01:40,950 --> 01:01:38,720
so that is the dream of dreams um of

1617
01:01:43,670 --> 01:01:40,960
course we have many steps to take

1618
01:01:46,069 --> 01:01:43,680
to make that possible

1619
01:01:48,069 --> 01:01:46,079
and right now of course

1620
01:01:49,589 --> 01:01:48,079
nasa and jpl are in the process of

1621
01:01:51,270 --> 01:01:49,599
studying

1622
01:01:53,270 --> 01:01:51,280
various types of missions that would get

1623
01:01:56,309 --> 01:01:53,280
us back out to europa

1624
01:01:59,029 --> 01:01:56,319
and we're optimistic that uh within the

1625
01:02:01,589 --> 01:01:59,039
next decade or so we will return to this

1626
01:02:02,470 --> 01:02:01,599
incredibly compelling world that that

1627
01:02:03,829 --> 01:02:02,480
could

1628
01:02:06,870 --> 01:02:03,839
harbor life

1629
01:02:08,870 --> 01:02:06,880
and so i'd like to close

1630
01:02:10,630 --> 01:02:08,880
with

1631
01:02:14,950 --> 01:02:10,640
one of my favorite images from the from

1632
01:02:19,029 --> 01:02:16,150
it's

1633
01:02:20,549 --> 01:02:19,039
an image carved

1634
01:02:22,150 --> 01:02:20,559
by

1635
01:02:23,349 --> 01:02:22,160
none other

1636
01:02:25,510 --> 01:02:23,359
than

1637
01:02:31,349 --> 01:02:25,520
galileo galilei

1638
01:02:36,549 --> 01:02:34,150

it's an image that galileo carefully

1639
01:02:41,589 --> 01:02:36,559
traced out night after night

1640
01:02:41,599 --> 01:02:46,150
there we go

1641
01:02:50,630 --> 01:02:47,430
there we are

1642
01:02:53,029 --> 01:02:50,640
um as you all know galileo turned his

1643
01:02:55,270 --> 01:02:53,039
telescope to the night sky

1644
01:02:57,349 --> 01:02:55,280
and carefully charted

1645
01:02:59,670 --> 01:02:57,359
jupiter and

1646
01:03:03,510 --> 01:02:59,680
he noticed these four tiny little specks

1647
01:03:06,150 --> 01:03:03,520
of light around jupiter now of course in

1648
01:03:07,270 --> 01:03:06,160
the in the early days of his uh

1649
01:03:09,270 --> 01:03:07,280
um

1650
01:03:11,029 --> 01:03:09,280
charting these little points of light he

1651
01:03:12,150 --> 01:03:11,039
initially thought that they were stars

1652
01:03:15,190 --> 01:03:12,160
and so

1653
01:03:16,710 --> 01:03:15,200
he named them the stars of medici

1654
01:03:19,270 --> 01:03:16,720
galileo was of course funded by the

1655
01:03:21,349 --> 01:03:19,280
medici family and he was no idiot so he

1656
01:03:23,190 --> 01:03:21,359
knew that

1657
01:03:25,430 --> 01:03:23,200
to keep the money rolling he should he

1658
01:03:28,230 --> 01:03:25,440
should uh

1659
01:03:30,710 --> 01:03:28,240
name something after his sponsor

1660
01:03:32,150 --> 01:03:30,720
but he soon realized that these stars

1661
01:03:34,710 --> 01:03:32,160
were moving

1662
01:03:36,630 --> 01:03:34,720
and night after night he charted them

1663
01:03:39,109 --> 01:03:36,640

and determined that in fact

1664
01:03:40,870 --> 01:03:39,119
those four little dots were not stars

1665
01:03:43,109 --> 01:03:40,880
they were moons they were moons of

1666
01:03:45,829 --> 01:03:43,119
jupiter and if jupiter had moons

1667
01:03:48,390 --> 01:03:45,839
then then it

1668
01:03:51,109 --> 01:03:48,400
must be similar to the earth

1669
01:03:54,150 --> 01:03:51,119
because of course earth had been

1670
01:03:57,029 --> 01:03:54,160
up until that point the only world that

1671
01:03:58,390 --> 01:03:57,039
had a moon and so if things were going

1672
01:04:01,910 --> 01:03:58,400
around jupiter

1673
01:04:02,710 --> 01:04:01,920
then that went against that aristotelian

1674
01:04:04,630 --> 01:04:02,720
view

1675
01:04:07,190 --> 01:04:04,640
of the earth being the center around

1676
01:04:09,670 --> 01:04:07,200
which everything else revolved

1677
01:04:13,510 --> 01:04:09,680
so with his careful charting of not just

1678
01:04:16,710 --> 01:04:13,520
jupiter but of course venus and the moon

1679
01:04:18,549 --> 01:04:16,720
galileo was able to put the final nail

1680
01:04:20,789 --> 01:04:18,559
in the coffin of aristo

1681
01:04:23,510 --> 01:04:20,799
aristotelian cosmology

1682
01:04:26,390 --> 01:04:23,520
and open the doorway to the copernican

1683
01:04:28,789 --> 01:04:26,400
revolution

1684
01:04:30,710 --> 01:04:28,799
and in the decades that would follow

1685
01:04:33,910 --> 01:04:30,720
galileo

1686
01:04:34,870 --> 01:04:33,920
we would come to learn and appreciate

1687
01:04:36,870 --> 01:04:34,880
that

1688
01:04:37,990 --> 01:04:36,880

the laws of physics

1689
01:04:40,470 --> 01:04:38,000
apply

1690
01:04:43,029 --> 01:04:40,480
not just here on earth but also

1691
01:04:44,710 --> 01:04:43,039
to these worlds and wonders beyond the

1692
01:04:46,630 --> 01:04:44,720
earth

1693
01:04:49,029 --> 01:04:46,640
and in the decades and centuries after

1694
01:04:51,349 --> 01:04:49,039
that with the advent of of spectroscopy

1695
01:04:53,990 --> 01:04:51,359
and new techniques for studying stars

1696
01:04:57,029 --> 01:04:54,000
and planets

1697
01:04:59,270 --> 01:04:57,039
would come to appreciate that

1698
01:05:00,789 --> 01:04:59,280
the principles of chemistry

1699
01:05:02,710 --> 01:05:00,799
apply

1700
01:05:05,510 --> 01:05:02,720
not just here on earth

1701
01:05:07,430 --> 01:05:05,520
but also on worlds and wonders beyond

1702
01:05:10,950 --> 01:05:07,440
the earth

1703
01:05:12,950 --> 01:05:10,960
and then with the advent of our robotic

1704
01:05:15,029 --> 01:05:12,960
exploration of the solar system

1705
01:05:17,750 --> 01:05:15,039
and our investigation of worlds like

1706
01:05:19,750 --> 01:05:17,760
mars and and mercury and venus

1707
01:05:22,630 --> 01:05:19,760
we would come to appreciate that the

1708
01:05:24,150 --> 01:05:22,640
principles of geology

1709
01:05:26,470 --> 01:05:24,160
apply

1710
01:05:29,270 --> 01:05:26,480
not just here on earth but also to these

1711
01:05:31,430 --> 01:05:29,280
worlds and wonders beyond earth

1712
01:05:34,150 --> 01:05:31,440
but when it comes to this

1713
01:05:37,829 --> 01:05:34,160

bizarre little thing we call life when

1714
01:05:40,870 --> 01:05:37,839
it comes to the the phenomenon of

1715
01:05:42,549 --> 01:05:40,880
life when it comes to the science of

1716
01:05:45,349 --> 01:05:42,559
biology

1717
01:05:49,589 --> 01:05:45,359
we have yet to make that leap

1718
01:05:53,190 --> 01:05:49,599
we don't yet know whether or not biology

1719
01:05:55,270 --> 01:05:53,200
works on worlds and wonders beyond earth

1720
01:05:56,390 --> 01:05:55,280
we have every reason to believe that it

1721
01:05:58,309 --> 01:05:56,400
should

1722
01:06:01,349 --> 01:05:58,319
our study of life on earth

1723
01:06:02,549 --> 01:06:01,359
leads us to think that that

1724
01:06:04,390 --> 01:06:02,559
life

1725
01:06:06,150 --> 01:06:04,400
is likely

1726
01:06:08,710 --> 01:06:06,160
everywhere where the conditions are

1727
01:06:11,270 --> 01:06:08,720
right but we have yet to do that

1728
01:06:13,750 --> 01:06:11,280
experiment

1729
01:06:14,710 --> 01:06:13,760
and part of what excites me

1730
01:06:17,029 --> 01:06:14,720
about

1731
01:06:19,029 --> 01:06:17,039
the time in which we live

1732
01:06:21,990 --> 01:06:19,039
part of what excites me about

1733
01:06:23,990 --> 01:06:22,000
the next few decades

1734
01:06:26,150 --> 01:06:24,000
is that for the first time in the

1735
01:06:29,670 --> 01:06:26,160
history of humanity

1736
01:06:31,029 --> 01:06:29,680
we have the tools and technology

1737
01:06:33,829 --> 01:06:31,039
to answer

1738
01:06:37,670 --> 01:06:33,839

this age-old question of whether or not

1739
01:06:40,069 --> 01:06:37,680
we are in fact alone in the universe

1740
01:06:42,870 --> 01:06:40,079
and so i hope that some

1741
01:06:45,109 --> 01:06:42,880
400 years from now

1742
01:06:47,910 --> 01:06:45,119
our descendants

1743
01:06:49,349 --> 01:06:47,920
we'll be able to look back at this time

1744
01:06:51,190 --> 01:06:49,359
in much the same way that we can look

1745
01:06:52,710 --> 01:06:51,200
back at the at the revolution that

1746
01:06:54,789 --> 01:06:52,720
galileo's

1747
01:06:56,950 --> 01:06:54,799
work began

1748
01:06:59,589 --> 01:06:56,960
our descendants some 400 years from now

1749
01:07:02,309 --> 01:06:59,599
will be able to look back

1750
01:07:05,190 --> 01:07:02,319
at this time in the history of human

1751
01:07:08,069 --> 01:07:05,200
exploration and scientific discovery

1752
01:07:11,829 --> 01:07:08,079
not just this time this place

1753
01:07:14,390 --> 01:07:11,839
the jpl a premier place in helping to

1754
01:07:16,390 --> 01:07:14,400
achieve the the exploration and the

1755
01:07:17,430 --> 01:07:16,400
science that needs to be done to to

1756
01:07:19,670 --> 01:07:17,440
advance

1757
01:07:21,589 --> 01:07:19,680
these kind of of discoveries

1758
01:07:23,589 --> 01:07:21,599
i hope our descendants will be able to

1759
01:07:26,150 --> 01:07:23,599
look back at this time

1760
01:07:27,589 --> 01:07:26,160
in this place and say

1761
01:07:28,870 --> 01:07:27,599
it was then

1762
01:07:31,190 --> 01:07:28,880
it was there

1763
01:07:32,549 --> 01:07:31,200

it was through the perseverance and the

1764
01:07:34,710 --> 01:07:32,559
exploration

1765
01:07:36,870 --> 01:07:34,720
that the discoveries were made that

1766
01:07:59,190 --> 01:07:36,880
brought the universe to life

1767
01:08:01,910 --> 01:08:00,870
so we may have a little bit of time for

1768
01:08:03,349 --> 01:08:01,920
questions and i think there's a

1769
01:08:04,870 --> 01:08:03,359
microphone there so if you have a

1770
01:08:13,750 --> 01:08:04,880
question to ask please if you would go

1771
01:08:17,910 --> 01:08:15,430
uh my name is abhi and i'm a summer

1772
01:08:20,229 --> 01:08:17,920
intern here at jpl my question is that

1773
01:08:22,229 --> 01:08:20,239
in a in a not completely unlikely event

1774
01:08:24,309 --> 01:08:22,239
of future nasa missions to europe are

1775
01:08:25,510 --> 01:08:24,319
being pushed further into future due to

1776
01:08:27,349 --> 01:08:25,520
budget cuts

1777
01:08:29,189 --> 01:08:27,359
what level of merit do you see in a

1778
01:08:32,309 --> 01:08:29,199
flyby mission to europa which could just

1779
01:08:34,309 --> 01:08:32,319
sniff the water plumes and maybe deduce

1780
01:08:35,349 --> 01:08:34,319
the chemistry lying beneath the icy

1781
01:08:36,789 --> 01:08:35,359
shell

1782
01:08:41,189 --> 01:08:36,799
yeah so

1783
01:08:46,550 --> 01:08:43,189
we don't yet have

1784
01:08:48,229 --> 01:08:46,560
definitive evidence of

1785
01:08:49,829 --> 01:08:48,239
plumes

1786
01:08:51,669 --> 01:08:49,839
that that we could then direct a

1787
01:08:55,349 --> 01:08:51,679
spacecraft to

1788
01:08:56,390 --> 01:08:55,359

i think that plumes are likely there

1789
01:08:58,870 --> 01:08:56,400
but

1790
01:08:59,990 --> 01:08:58,880
if we were just to do a quick and dirty

1791
01:09:02,870 --> 01:09:00,000
mission

1792
01:09:04,870 --> 01:09:02,880
that's very simple

1793
01:09:06,390 --> 01:09:04,880
it would be a little bit hard to know

1794
01:09:07,990 --> 01:09:06,400
exactly

1795
01:09:09,030 --> 01:09:08,000
where the best place is to capture

1796
01:09:16,309 --> 01:09:09,040
material

1797
01:09:18,950 --> 01:09:17,349
hello

1798
01:09:20,550 --> 01:09:18,960
in regard to

1799
01:09:21,430 --> 01:09:20,560
the auroras

1800
01:09:23,189 --> 01:09:21,440
of

1801
01:09:24,950 --> 01:09:23,199
europa

1802
01:09:27,430 --> 01:09:24,960
is it possible

1803
01:09:29,590 --> 01:09:27,440
that they will discover

1804
01:09:31,590 --> 01:09:29,600
microbial life

1805
01:09:32,709 --> 01:09:31,600
in the plumes of

1806
01:09:35,510 --> 01:09:32,719
europa

1807
01:09:37,110 --> 01:09:35,520
like they have uh discovered it in

1808
01:09:38,550 --> 01:09:37,120
enceladus

1809
01:09:41,030 --> 01:09:38,560
well so

1810
01:09:42,709 --> 01:09:41,040
at enceladus we haven't yet found life

1811
01:09:44,390 --> 01:09:42,719
in the in the plume water but we have

1812
01:09:47,030 --> 01:09:44,400
found some some compelling organic

1813
01:09:49,030 --> 01:09:47,040

chemistry and that of course makes

1814
01:09:50,229 --> 01:09:49,040
enceladus an incredibly exciting target

1815
01:09:51,749 --> 01:09:50,239
to go back to

1816
01:09:54,149 --> 01:09:51,759
and i want to explore all of these

1817
01:09:55,750 --> 01:09:54,159
worlds uh in my opinion we should be

1818
01:09:57,510 --> 01:09:55,760
getting spacecraft out there doing

1819
01:09:58,470 --> 01:09:57,520
science uh all throughout the solar

1820
01:09:59,910 --> 01:09:58,480
system

1821
01:10:01,270 --> 01:09:59,920
and um

1822
01:10:02,630 --> 01:10:01,280
and so

1823
01:10:04,229 --> 01:10:02,640
one of the

1824
01:10:07,350 --> 01:10:04,239
but but the fundamental of your question

1825
01:10:08,950 --> 01:10:07,360
now could if there was microbial life in

1826
01:10:10,790 --> 01:10:08,960
the in the ocean

1827
01:10:13,189 --> 01:10:10,800
would it be ejected out and and could we

1828
01:10:14,950 --> 01:10:13,199
be able to would we be able to catch it

1829
01:10:16,870 --> 01:10:14,960
um

1830
01:10:19,270 --> 01:10:16,880
at this point in time we don't really

1831
01:10:20,390 --> 01:10:19,280
know we're doing some experiments to try

1832
01:10:22,870 --> 01:10:20,400
and see

1833
01:10:24,630 --> 01:10:22,880
uh whether or not for instance in

1834
01:10:26,149 --> 01:10:24,640
earth's ocean if you took

1835
01:10:29,510 --> 01:10:26,159
the microbial

1836
01:10:31,270 --> 01:10:29,520
cell densities in earth's ocean water

1837
01:10:34,310 --> 01:10:31,280
and pretended that that was europa's

1838
01:10:36,229 --> 01:10:34,320

ocean water or enceladus ocean water

1839
01:10:37,669 --> 01:10:36,239
how much

1840
01:10:39,750 --> 01:10:37,679
material would you have to collect

1841
01:10:41,669 --> 01:10:39,760
before you captured one cell

1842
01:10:42,950 --> 01:10:41,679
we don't know the answer to that quite

1843
01:10:44,310 --> 01:10:42,960
yet but

1844
01:10:45,669 --> 01:10:44,320
but that's part of the work that we're

1845
01:10:46,790 --> 01:10:45,679
doing to sort of fold into these

1846
01:10:47,830 --> 01:10:46,800
missions

1847
01:10:52,470 --> 01:10:47,840
thank you

1848
01:10:57,669 --> 01:10:55,669
could you tell me anything about the

1849
01:10:59,350 --> 01:10:57,679
work or if there is any work being done

1850
01:11:02,390 --> 01:10:59,360
to look deeper

1851
01:11:04,149 --> 01:11:02,400
into the hydrothermal vents themselves

1852
01:11:06,149 --> 01:11:04,159
you know we look at them when they reach

1853
01:11:07,910 --> 01:11:06,159
the open ocean

1854
01:11:10,470 --> 01:11:07,920
i don't know how much water content you

1855
01:11:11,510 --> 01:11:10,480
have and what's being pumped out of them

1856
01:11:13,430 --> 01:11:11,520
but

1857
01:11:16,470 --> 01:11:13,440
you know what is there a possibility of

1858
01:11:18,870 --> 01:11:16,480
life deeper within those systems and is

1859
01:11:20,310 --> 01:11:18,880
there a way to actually plumb them with

1860
01:11:21,830 --> 01:11:20,320
instrumentation

1861
01:11:24,390 --> 01:11:21,840
yeah that's a that's a great question

1862
01:11:27,750 --> 01:11:24,400
and and there is uh some very nice work

1863
01:11:31,430 --> 01:11:27,760

being done uh a number of different

1864
01:11:34,070 --> 01:11:31,440
institutions uh woods hall um

1865
01:11:35,669 --> 01:11:34,080
university of washington seattle scripps

1866
01:11:37,030 --> 01:11:35,679
uh usc

1867
01:11:40,390 --> 01:11:37,040
uh and there's a project called the

1868
01:11:43,030 --> 01:11:40,400
ocean drilling program that has as

1869
01:11:45,590 --> 01:11:43,040
sort of a a component of it looking in

1870
01:11:46,950 --> 01:11:45,600
areas that uh that have or had

1871
01:11:48,149 --> 01:11:46,960
hydrothermal vents

1872
01:11:50,149 --> 01:11:48,159
um

1873
01:11:52,390 --> 01:11:50,159
but this sort of folds into

1874
01:11:55,350 --> 01:11:52,400
a passion of mine which is developing

1875
01:11:56,870 --> 01:11:55,360
the robotic tools to do exactly what

1876
01:11:58,630 --> 01:11:56,880
you're saying

1877
01:12:01,669 --> 01:11:58,640
so we can actually kind of

1878
01:12:03,510 --> 01:12:01,679
dive even deeper into the into the the

1879
01:12:05,430 --> 01:12:03,520
channels of

1880
01:12:08,950 --> 01:12:05,440
of water that are that are being cycled

1881
01:12:11,030 --> 01:12:08,960
up through our ocean floor

1882
01:12:12,550 --> 01:12:11,040
hi my name is andrew i'm a summer intern

1883
01:12:15,189 --> 01:12:12,560
a great presentation it was really

1884
01:12:17,350 --> 01:12:15,199
interesting and i just have one question

1885
01:12:19,270 --> 01:12:17,360
if regardless of whether or not we drill

1886
01:12:20,630 --> 01:12:19,280
down and find life or not once we do

1887
01:12:22,550 --> 01:12:20,640
drill down we're going to likely

1888
01:12:24,709 --> 01:12:22,560

contaminate what's in there so what are

1889
01:12:26,229 --> 01:12:24,719
some means that jpl and nasa are working

1890
01:12:28,149 --> 01:12:26,239
with to prevent that from happening

1891
01:12:29,110 --> 01:12:28,159
thank you yeah that's a great question

1892
01:12:33,750 --> 01:12:29,120
um

1893
01:12:38,470 --> 01:12:33,760
the

1894
01:12:40,310 --> 01:12:38,480
planetary protection officer at nasa

1895
01:12:42,709 --> 01:12:40,320
headquarters

1896
01:12:44,390 --> 01:12:42,719
worked very closely on addressing these

1897
01:12:46,790 --> 01:12:44,400
issues and any mission

1898
01:12:49,590 --> 01:12:46,800
that would go

1899
01:12:52,709 --> 01:12:49,600
near europa or onto the surface

1900
01:12:55,990 --> 01:12:53,830
undergo

1901
01:12:58,310 --> 01:12:56,000
a lot of cleaning and sterilization to

1902
01:12:59,590 --> 01:12:58,320
make sure that we don't bring any earth

1903
01:13:01,910 --> 01:12:59,600
microbes

1904
01:13:03,590 --> 01:13:01,920
to that potentially habitable ocean

1905
01:13:05,430 --> 01:13:03,600
because of course the last thing we want

1906
01:13:06,870 --> 01:13:05,440
to do is

1907
01:13:08,790 --> 01:13:06,880
find a false positive we don't want to

1908
01:13:12,149 --> 01:13:08,800
go all the way to europa and find an

1909
01:13:13,510 --> 01:13:12,159
earth microbe and more importantly

1910
01:13:16,630 --> 01:13:13,520
we don't want to

1911
01:13:18,790 --> 01:13:16,640
destroy europa for the europeans

1912
01:13:20,790 --> 01:13:18,800
you know it's a if they've got something

1913
01:13:22,229 --> 01:13:20,800

going on in that ocean we should we

1914
01:13:24,709 --> 01:13:22,239
should let them keep doing what they're

1915
01:13:27,270 --> 01:13:25,910
i was wondering if you can calculate

1916
01:13:29,189 --> 01:13:27,280
theoretically the thickness of the

1917
01:13:30,470 --> 01:13:29,199
isolator on europa based on the tidal

1918
01:13:31,910 --> 01:13:30,480
energy

1919
01:13:33,910 --> 01:13:31,920
and the temperature receives from the

1920
01:13:36,229 --> 01:13:33,920
sun yeah um

1921
01:13:37,430 --> 01:13:36,239
that's a that's another great question

1922
01:13:39,750 --> 01:13:37,440
it's um

1923
01:13:41,510 --> 01:13:39,760
there are dozens of papers published on

1924
01:13:43,669 --> 01:13:41,520
the topic and

1925
01:13:46,390 --> 01:13:43,679
not much of a consensus has been reached

1926
01:13:48,470 --> 01:13:46,400
uh in part because

1927
01:13:50,630 --> 01:13:48,480
different processes happen

1928
01:13:52,470 --> 01:13:50,640
for slightly different thicknesses in

1929
01:13:54,709 --> 01:13:52,480
terms of convection and conduction of

1930
01:13:56,790 --> 01:13:54,719
heat out from the interior

1931
01:13:58,870 --> 01:13:56,800
and so

1932
01:14:00,950 --> 01:13:58,880
some scientists think that europa's

1933
01:14:03,590 --> 01:14:00,960
ocean europa's ice shell

1934
01:14:06,070 --> 01:14:03,600
is say 15 kilometers in thickness

1935
01:14:09,430 --> 01:14:06,080
and much of that 15 kilometers

1936
01:14:11,590 --> 01:14:09,440
is ice that is slowly convecting to

1937
01:14:13,350 --> 01:14:11,600
transport heat and then it's overlaying

1938
01:14:14,870 --> 01:14:13,360

by a brittle lid

1939
01:14:17,110 --> 01:14:14,880
other scientists think that it's

1940
01:14:19,350 --> 01:14:17,120
actually quite a thin shell maybe a few

1941
01:14:21,030 --> 01:14:19,360
kilometers in thickness and most of the

1942
01:14:22,310 --> 01:14:21,040
heat is being dissipated via via

1943
01:14:24,070 --> 01:14:22,320
conduction

1944
01:14:25,669 --> 01:14:24,080
so

1945
01:14:27,910 --> 01:14:25,679
it's a topic of much debate and it's one

1946
01:14:29,669 --> 01:14:27,920
of the key questions that any future

1947
01:14:33,910 --> 01:14:29,679
mission would uh

1948
01:14:37,030 --> 01:14:35,030
hello thank you so much for your

1949
01:14:39,350 --> 01:14:37,040
presentations really wonderful and by

1950
01:14:41,350 --> 01:14:39,360
the way i really enjoyed europa report

1951
01:14:43,270 --> 01:14:41,360
okay well thank you everybody should see

1952
01:14:44,390 --> 01:14:43,280
it i wanted to ask you about the

1953
01:14:45,669 --> 01:14:44,400
interesting news that came out a few

1954
01:14:47,270 --> 01:14:45,679
months ago from the university of

1955
01:14:49,350 --> 01:14:47,280
washington of a paper

1956
01:14:51,110 --> 01:14:49,360
that talked about um

1957
01:14:52,390 --> 01:14:51,120
the ability to find certain molecules

1958
01:14:54,550 --> 01:14:52,400
and distant planets potentially

1959
01:14:56,709 --> 01:14:54,560
exoplanets that could be indicators of

1960
01:14:58,630 --> 01:14:56,719
life and i'd

1961
01:15:01,510 --> 01:14:58,640
correct me is it dimer molecules or

1962
01:15:03,270 --> 01:15:01,520
dimmer molecules dimers yeah

1963
01:15:04,790 --> 01:15:03,280

and is that something that's relevant to

1964
01:15:06,390 --> 01:15:04,800
europa or enceladus or any of these

1965
01:15:08,149 --> 01:15:06,400
outer ocean worlds and and where are we

1966
01:15:10,070 --> 01:15:08,159
getting in terms of our

1967
01:15:11,669 --> 01:15:10,080
space telescopes potentially the james

1968
01:15:13,990 --> 01:15:11,679
webb in terms of being able to detect

1969
01:15:15,350 --> 01:15:14,000
those molecules on worlds even farther

1970
01:15:17,350 --> 01:15:15,360
out that may indicate the presence of

1971
01:15:18,790 --> 01:15:17,360
life or photosynthesis or

1972
01:15:19,830 --> 01:15:18,800
something happening on one of those

1973
01:15:21,270 --> 01:15:19,840
planets that might be interesting to

1974
01:15:23,350 --> 01:15:21,280
explore further

1975
01:15:25,990 --> 01:15:23,360
yeah here again i wish we could be

1976
01:15:27,590 --> 01:15:26,000
moving faster

1977
01:15:29,990 --> 01:15:27,600
there are ground-based telescopes the

1978
01:15:31,910 --> 01:15:30,000
30-millimeter telescope out in hawaii of

1979
01:15:33,990 --> 01:15:31,920
course james webb

1980
01:15:35,030 --> 01:15:34,000
and potentially some

1981
01:15:37,590 --> 01:15:35,040
some

1982
01:15:39,830 --> 01:15:37,600
smaller space-based telescopes that that

1983
01:15:41,110 --> 01:15:39,840
will come online

1984
01:15:43,350 --> 01:15:41,120
in the not too distant future that will

1985
01:15:46,390 --> 01:15:43,360
help be able to do spectroscopy of of

1986
01:15:47,830 --> 01:15:46,400
these um exoplanet atmospheres

1987
01:15:49,350 --> 01:15:47,840
uh

1988
01:15:51,830 --> 01:15:49,360

i wish we could move faster on that

1989
01:15:53,750 --> 01:15:51,840
because it's such a fascinating area for

1990
01:15:58,390 --> 01:15:53,760
exploration

1991
01:16:01,910 --> 01:16:01,110
when we do eventually find

1992
01:16:16,070 --> 01:16:01,920
a

1993
01:16:17,990 --> 01:16:16,080
left

1994
01:16:19,510 --> 01:16:18,000
unless we train our radio telescopes or

1995
01:16:21,110 --> 01:16:19,520
our optical telescopes and find some

1996
01:16:22,630 --> 01:16:21,120
steady signal of intelligent

1997
01:16:24,310 --> 01:16:22,640
civilizations there

1998
01:16:26,709 --> 01:16:24,320
that one of the limitations of

1999
01:16:28,950 --> 01:16:26,719
exoplanets or one of the defining

2000
01:16:30,390 --> 01:16:28,960
attributes is that they are far away

2001
01:16:32,149 --> 01:16:30,400
and so

2002
01:16:35,189 --> 01:16:32,159
someday we will know

2003
01:16:36,709 --> 01:16:35,199
that there's a

2004
01:16:39,430 --> 01:16:36,719
habitable planet out there but then it

2005
01:16:42,149 --> 01:16:39,440
will take us a long time to get there if

2006
01:16:44,630 --> 01:16:42,159
they're not beaming communications to us

2007
01:16:45,910 --> 01:16:44,640
and that in part is is sort of what drew

2008
01:16:50,229 --> 01:16:45,920
me to

2009
01:16:54,790 --> 01:16:53,750
17 years ago or so at this point

2010
01:16:57,430 --> 01:16:54,800
is that

2011
01:16:59,750 --> 01:16:57,440
worlds like europa and enceladus are

2012
01:17:01,350 --> 01:16:59,760
worlds where we can actually send a

2013
01:17:04,149 --> 01:17:01,360

robotic spacecraft

2014
01:17:06,070 --> 01:17:04,159
to to look for living life and and you

2015
01:17:08,390 --> 01:17:06,080
know something that we can we can touch

2016
01:17:10,149 --> 01:17:08,400
and feel and and determine its

2017
01:17:11,750 --> 01:17:10,159
fundamental biochemistry

2018
01:17:13,830 --> 01:17:11,760
so uh i look forward to future

2019
01:17:15,430 --> 01:17:13,840
discoveries on exoplanets and that will

2020
01:17:17,669 --> 01:17:15,440
be moving along in parallel with our

2021
01:17:19,270 --> 01:17:17,679
exploration of our own solar system

2022
01:17:21,270 --> 01:17:19,280
i hope you get more funding to do it you

2023
01:17:23,750 --> 01:17:21,280
got to get those landers to uh

2024
01:17:24,790 --> 01:17:23,760
to europa oh well thank you we've got

2025
01:17:27,189 --> 01:17:24,800
lots of

2026
01:17:29,990 --> 01:17:27,199
bright young minds that are that are

2027
01:17:33,669 --> 01:17:30,000
uh excited about stem education who

2028
01:17:36,790 --> 01:17:35,830
well again a wonderful talk thank you so

2029
01:17:39,270 --> 01:17:36,800
much

2030
01:17:41,830 --> 01:17:39,280
and my question is i know there's a lot

2031
01:17:43,189 --> 01:17:41,840
of possibilities for the next mission to

2032
01:17:45,110 --> 01:17:43,199
go to europa

2033
01:17:47,590 --> 01:17:45,120
depending on what nasa's funding is what

2034
01:17:49,990 --> 01:17:47,600
congress decides and that sort of thing

2035
01:17:51,270 --> 01:17:50,000
which is a real game sometimes but

2036
01:17:54,390 --> 01:17:51,280
what's the most

2037
01:17:56,630 --> 01:17:54,400
concrete mission that is

2038
01:17:58,790 --> 01:17:56,640

at the forefront of heading out to

2039
01:18:00,870 --> 01:17:58,800
europa at this point where does that

2040
01:18:03,430 --> 01:18:00,880
stand and you know about maybe how long

2041
01:18:05,990 --> 01:18:03,440
it might take to send that off

2042
01:18:10,510 --> 01:18:06,000
yeah so um

2043
01:18:13,270 --> 01:18:10,520
a great resource um is to go to

2044
01:18:15,990 --> 01:18:13,280
europa.jpl.nasa.gov and that's got

2045
01:18:17,430 --> 01:18:16,000
all of the publicly available reports

2046
01:18:20,310 --> 01:18:17,440
and documentation

2047
01:18:22,229 --> 01:18:20,320
and another great resources

2048
01:18:24,070 --> 01:18:22,239
so within nasa there are these

2049
01:18:26,630 --> 01:18:24,080
assessment groups

2050
01:18:28,310 --> 01:18:26,640
for various regions and the outer

2051
01:18:31,110 --> 01:18:28,320
planets assessment group

2052
01:18:31,990 --> 01:18:31,120
or opaque if you just google

2053
01:18:33,910 --> 01:18:32,000
uh

2054
01:18:36,390 --> 01:18:33,920
opaque you'll find

2055
01:18:38,709 --> 01:18:36,400
lots of archived mission studies

2056
01:18:40,390 --> 01:18:38,719
and one of the the studies that

2057
01:18:43,110 --> 01:18:40,400
you'll find there is on the europa

2058
01:18:45,270 --> 01:18:43,120
clipper which is a mission that's being

2059
01:18:48,310 --> 01:18:45,280
studied and

2060
01:18:51,510 --> 01:18:48,320
analyzed here at jpl and other centers

2061
01:18:54,790 --> 01:18:51,520
and that mission would

2062
01:18:56,709 --> 01:18:54,800
if funded it would fly by europa

2063
01:18:58,790 --> 01:18:56,719

and be able to

2064
01:19:01,270 --> 01:18:58,800
examine the surface in great detail both

2065
01:19:03,270 --> 01:19:01,280
with imagery and spectroscopy

2066
01:19:05,830 --> 01:19:03,280
it would potentially utilize ice

2067
01:19:08,550 --> 01:19:05,840
penetrating radar to

2068
01:19:10,630 --> 01:19:08,560
probe into the ice and look for

2069
01:19:14,310 --> 01:19:10,640
water pockets and

2070
01:19:18,070 --> 01:19:15,910
and it would have many other instruments

2071
01:19:20,550 --> 01:19:18,080
that would help us assess the

2072
01:19:22,550 --> 01:19:20,560
habitability of europa so google around

2073
01:19:24,310 --> 01:19:22,560
and look for europa clipper

2074
01:19:25,830 --> 01:19:24,320
and you'll also find all sorts of other

2075
01:19:28,310 --> 01:19:25,840
studies that

2076
01:19:31,510 --> 01:19:28,320
that nasa has done

2077
01:19:33,910 --> 01:19:33,110
and we got a couple of questions from

2078
01:19:37,910 --> 01:19:33,920
the

2079
01:19:39,750 --> 01:19:37,920
web thank you

2080
01:19:41,830 --> 01:19:39,760
is the theory that europa is getting

2081
01:19:43,669 --> 01:19:41,840
geothermal activity from the title

2082
01:19:46,630 --> 01:19:43,679
squeezing of jupiter's gravitational

2083
01:19:48,709 --> 01:19:46,640
pressures yeah so the um

2084
01:19:51,590 --> 01:19:48,719
uh the questions about that title tug

2085
01:19:53,590 --> 01:19:51,600
and pull and

2086
01:19:56,470 --> 01:19:53,600
the reason why we think europa has this

2087
01:19:58,790 --> 01:19:56,480
liquid water ocean is because of that

2088
01:20:00,149 --> 01:19:58,800

that squeezing as europa goes around in

2089
01:20:01,669 --> 01:20:00,159
its slightly

2090
01:20:04,149 --> 01:20:01,679
elliptical orbit

2091
01:20:06,470 --> 01:20:04,159
just imagine io

2092
01:20:09,510 --> 01:20:06,480
but now cover it

2093
01:20:12,070 --> 01:20:09,520
cover it in ice and and

2094
01:20:16,870 --> 01:20:12,080
dial back the volcanism a little bit

2095
01:20:21,910 --> 01:20:20,470
what would europa's energy source be

2096
01:20:24,310 --> 01:20:21,920
for life

2097
01:20:26,390 --> 01:20:24,320
well if europa has an active seafloor

2098
01:20:28,310 --> 01:20:26,400
there could be hydrothermal vents

2099
01:20:31,030 --> 01:20:28,320
but then another aspect of the energy

2100
01:20:33,189 --> 01:20:31,040
equation for habitability on europa

2101
01:20:35,990 --> 01:20:33,199
comes back to the surface

2102
01:20:38,470 --> 01:20:36,000
where some of the work

2103
01:20:40,149 --> 01:20:38,480
i do and my colleagues do here at jpl is

2104
01:20:42,070 --> 01:20:40,159
looking at the surface radiation

2105
01:20:44,310 --> 01:20:42,080
chemistry and we actually know that

2106
01:20:45,270 --> 01:20:44,320
europa's surface ice

2107
01:20:47,669 --> 01:20:45,280
has

2108
01:20:50,390 --> 01:20:47,679
molecular oxygen trapped in it

2109
01:20:53,030 --> 01:20:50,400
it's got sulfate it's got carbon dioxide

2110
01:20:56,229 --> 01:20:53,040
it's got all of these compounds that

2111
01:20:58,229 --> 01:20:56,239
life on earth loves to eat and so if

2112
01:21:02,229 --> 01:20:58,239
some of that surface ice mixes into the

2113
01:21:03,990 --> 01:21:02,239

ocean below that could be a very

2114
01:21:06,550 --> 01:21:04,000
valuable chemical energy resource for

2115
01:21:07,910 --> 01:21:06,560
life within europa

2116
01:21:10,070 --> 01:21:07,920
and i'll just take one more here is

2117
01:21:12,310 --> 01:21:10,080
there any reasonable prospect that we

2118
01:21:14,310 --> 01:21:12,320
might find complex life forms

2119
01:21:17,510 --> 01:21:14,320
in the european ocean like the ones we

2120
01:21:20,390 --> 01:21:17,520
have in earth's hydrothermal vents um

2121
01:21:22,709 --> 01:21:20,400
a very interesting question and um

2122
01:21:24,629 --> 01:21:22,719
from an energy standpoint

2123
01:21:26,709 --> 01:21:24,639
it could be that that

2124
01:21:28,950 --> 01:21:26,719
so complex life on earth

2125
01:21:31,990 --> 01:21:28,960
even at those hydrothermal vents

2126
01:21:34,629 --> 01:21:32,000
it depends on oxygen that is produced

2127
01:21:36,229 --> 01:21:34,639
via photosynthesis so those tube worms

2128
01:21:37,510 --> 01:21:36,239
those shrimp those other creatures that

2129
01:21:39,750 --> 01:21:37,520
you see

2130
01:21:41,430 --> 01:21:39,760
they are breathing oxygen that's

2131
01:21:42,550 --> 01:21:41,440
dissolved in the ocean water and that

2132
01:21:44,950 --> 01:21:42,560
oxygen

2133
01:21:46,390 --> 01:21:44,960
comes from photosynthesis on the surface

2134
01:21:48,149 --> 01:21:46,400
of the earth

2135
01:21:50,390 --> 01:21:48,159
on europa we're not going to have

2136
01:21:51,430 --> 01:21:50,400
necessarily photosynthesis generating

2137
01:21:54,790 --> 01:21:51,440
oxygen

2138
01:21:57,110 --> 01:21:54,800

but we do have this radiation chemistry

2139
01:22:00,149 --> 01:21:57,120
that is bombarding europa's surface

2140
01:22:02,070 --> 01:22:00,159
producing uh that molecular oxygen that

2141
01:22:03,669 --> 01:22:02,080
that i mentioned and so if some of that

2142
01:22:05,510 --> 01:22:03,679
molecular oxygen

2143
01:22:08,709 --> 01:22:05,520
is mixed into the ocean

2144
01:22:11,030 --> 01:22:08,719
there could be enough oxygen

2145
01:22:12,310 --> 01:22:11,040
to potentially power complex life as we

2146
01:22:14,709 --> 01:22:12,320
know it

2147
01:22:17,189 --> 01:22:14,719
but from an evolutionary standpoint

2148
01:22:18,629 --> 01:22:17,199
uh this becomes a very intriguing

2149
01:22:20,390 --> 01:22:18,639
question

2150
01:22:23,270 --> 01:22:20,400
what

2151
01:22:27,430 --> 01:22:23,280
made complex life on earth possible

2152
01:22:29,430 --> 01:22:27,440
is it from an evolutionary standpoint

2153
01:22:31,590 --> 01:22:29,440
contingent on some events

2154
01:22:33,270 --> 01:22:31,600
or is it a sort of convergent

2155
01:22:36,229 --> 01:22:33,280
evolutionary process

2156
01:22:38,550 --> 01:22:36,239
will complex life arise on any world

2157
01:22:41,590 --> 01:22:38,560
that's got enough energy to help power

2158
01:22:43,430 --> 01:22:41,600
it we don't know and so going to europa

2159
01:22:45,110 --> 01:22:43,440
looking at some of that ocean chemistry

2160
01:22:47,270 --> 01:22:45,120
and potentially finding not just simple

2161
01:22:50,390 --> 01:22:47,280
life forms but more complex life forms

2162
01:22:52,550 --> 01:22:50,400
is something that i uh dream of doing

2163
01:22:54,070 --> 01:22:52,560

so i'll finish there and thank you again